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FORECASTING FREEZING PRECIPITATION IN CENTRAL EUROPE

by

Herr Harald Strauss
Capt David Rust
SMSgt D.G. McGrew
Sgt Francis Tower

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PREFACE

This publication is the result of a freezing precipitation workshop held 25 October 1985 at 31st Weather Squadron. Representatives from 2 WW, 7 WS, USAREUR Forecast Unit, and each of the 31 WS units in central Europe attended. The goal was to share knowledge on freezing precipitation and develop a common worksheet for all central European forecasters in 2 WW to use. ~~Herr Harald Strauss, 2 WW/DNC,~~ presented typical climatology for freezing precipitation situations and several case studies of actual occurrences. Following input from each forecaster on his/her unit's method of forecasting freezing precipitation, the group combined efforts to develop the freezing precipitation worksheet.

James H. Love, Jr., Capt, USAF
Chief, Scientific Services Branch
HQ 31st Weather Squadron
June 1986

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CHAPTER 1

Climatology

1. Based solely on the winter of 1985, one may conclude that freezing precipitation occurs as frequently in central Europe, especially Germany, as over the northern U.S. However, since the winter of 1985 was unusual, the question arises, "What is the average threat or how frequent is freezing precipitation in a typical central European winter?" The RUSSWO or LISOCS provides the best answer. Figures 1 and 2 show the relative frequency of all precipitation at various 31 WS stations and the frequency of freezing precipitation in December and January at all hours. From this we can see that freezing rain and/or drizzle occurs less than 2 percent of the time, a value that seems negligible. Therefore, a "smart" forecaster will ignore forecasting freezing precipitation, using the argument that since it seems to occur so randomly, why make a fuss.

2. Another approach to the frequency of freezing precipitation occurrences shows that this "rare event" feeling is wrong. A pilot study with freezing precipitation occurrences during the last 5 years at Ramstein AB revealed that this type of precipitation lasts approximately 4 hours. December and January together have 1488 hours. Multiplying this with the normal frequency, i.e., 1.0 percent gives approximately 15 hours. This, divided by the normal 4 hours duration results in 4 days or roughly 6 percent of all days in December and January. Because of its extremely high influence upon operations (usually closure of the base), an unpredicted event causes high level interest. Using this argument, freezing precipitation is not something to be ignored.

3. Within the "peak season" (December and January) there occur some diurnal and regional differences. Generally speaking, freezing precipitation can occur any time during the day in Germany but mainly occurs during the time of the lowest temperatures in the Netherlands. Table 1 shows the relative frequency of occurrence of freezing precipitation by times of the day. Over south-western Germany, during December, there is only a weak tendency for freezing rain to occur more often in the morning, whereas January has a slight maximum around noon. During December in the Netherlands (and presumably also in western Belgium), freezing precipitation is very much restricted to the morning hours. During January there is a distinct maximum in the morning and a minimum in the afternoon.

4. For freezing precipitation to occur, the air aloft must be warm enough and deep enough to melt the falling snow while the air near the ground must be cold enough to refreeze the precipitation. Therefore, the ideal case is a warm front moving from the Atlantic, over France, and into Germany ending a period of subfreezing temperatures which have persisted long enough to freeze the first 5-10 cm of the ground. This is the classic removal of modified continental polar air by modified maritime tropical air. Such a situation occurred 8 December, 1978.

5. Figure 3 shows the surface analysis from 7 Dec 78, 12Z, approximately 24 hrs before the freezing precipitation began. A deep and extensive low covering most of the North Atlantic Ocean. A high pressure over Scandinavia and eastern Europe, caused a strong temperature gradient between western

and eastern France. Germany though, was still under cold air. Note the outflow of cold air over the North Sea indicated by strong southeasterly winds. At 850 mb (fig 4) warm air covered all of France and Germany, with high dewpoints (moist air) over France and low dewpoints (subsiding air) over Germany. From this it is clear that precipitation moving into Germany from France, would be rain. Conditions at 700 mb (fig 5) were similar to those at 850 mb. The near freezing temperatures over France indicated the tropical origin of the warm air. Finally, figure 6 showed thickness values greater than 5400 gpm, not a good indicator of snow.

6. The typical problem for such straight forward situations is not snow or rain, it is rain or freezing rain. Will the cold air at the surface be pushed out prior to the start of the warm-frontal rain? Figure 7 provides the answer. Southwestern Germany received freezing precipitation with surface temperatures well below freezing. The reason is that south of the Eifel, Westerwald, Sauerland, and Harz mountains, a shallow easterly to northeasterly surface flow developed. It kept southern and southwestern Germany in the cold air while the warm front overran it. This effect is often strong enough to prevent major warming after the warm front passes. Instead, turbulent mixing gradually increases temperatures, frequently resulting in dense mixing fog with zero-zero conditions and occasional drizzle.

7. Unfortunately, not all freezing precipitations situations are as clear cut as this one. There are many cases where temperatures at 850mb did not go above freezing. Alternatively, strong upper-level winds may suggest turbulent mixing would warm the air ahead of the front and prevent freezing precipitation. Although good predictors for freezing precipitation don't abound, a preliminary study for Ramstein AB suggest that 850 and 700mb temperatures could prove useful.

8. Based on a very limited data set of freezing precipitation occurrences at Ramstein AB, Table 2 associates freezing precipitation with upper air parameters. This scant study suggests that the use of both 850 and 700mb thresholds provides a better predictor for freezing precipitation than single predictors (e.g., T_{850}, T_{700}, or 500-1000mb thickness). Although the evidence suggests that 500-1000mb thickness or 700-1000mb thickness may be a better predictor, we have found no studies at this point in time.

9. Chapter 2 presents a series of case studies of freezing precipitations situations in central Europe. As we go through these cases and point out the indicators which were present to forecast the events, we will also relate the usefulness of the thresholds given in Table 2. We have limited this study to central Europe because freezing precipitation is a very rare event in the U.K. (due to mixing) and the Med (lack of cold air).

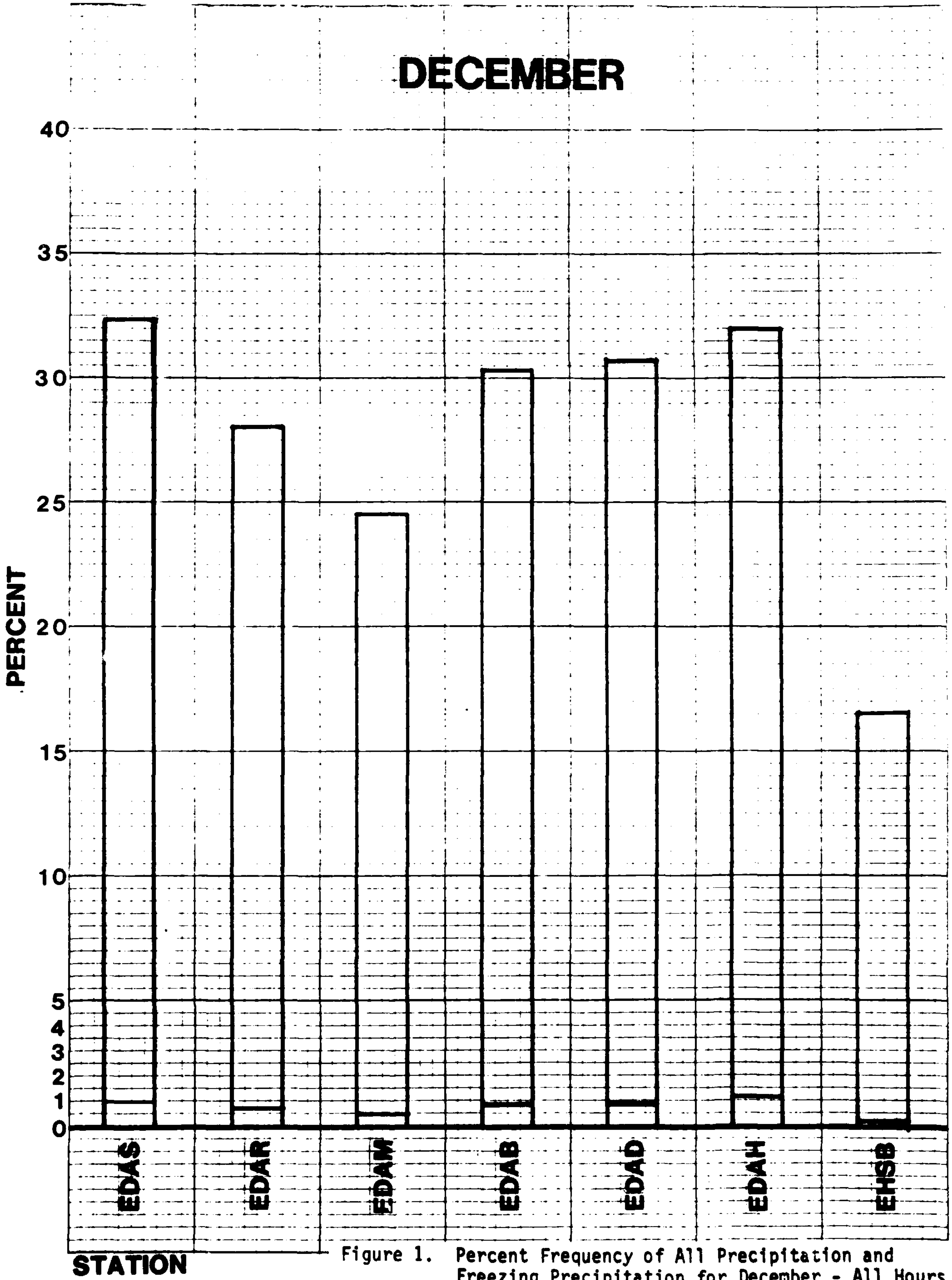

Figure 1. Percent Frequency of All Precipitation and Freezing Precipitation for December - All Hours

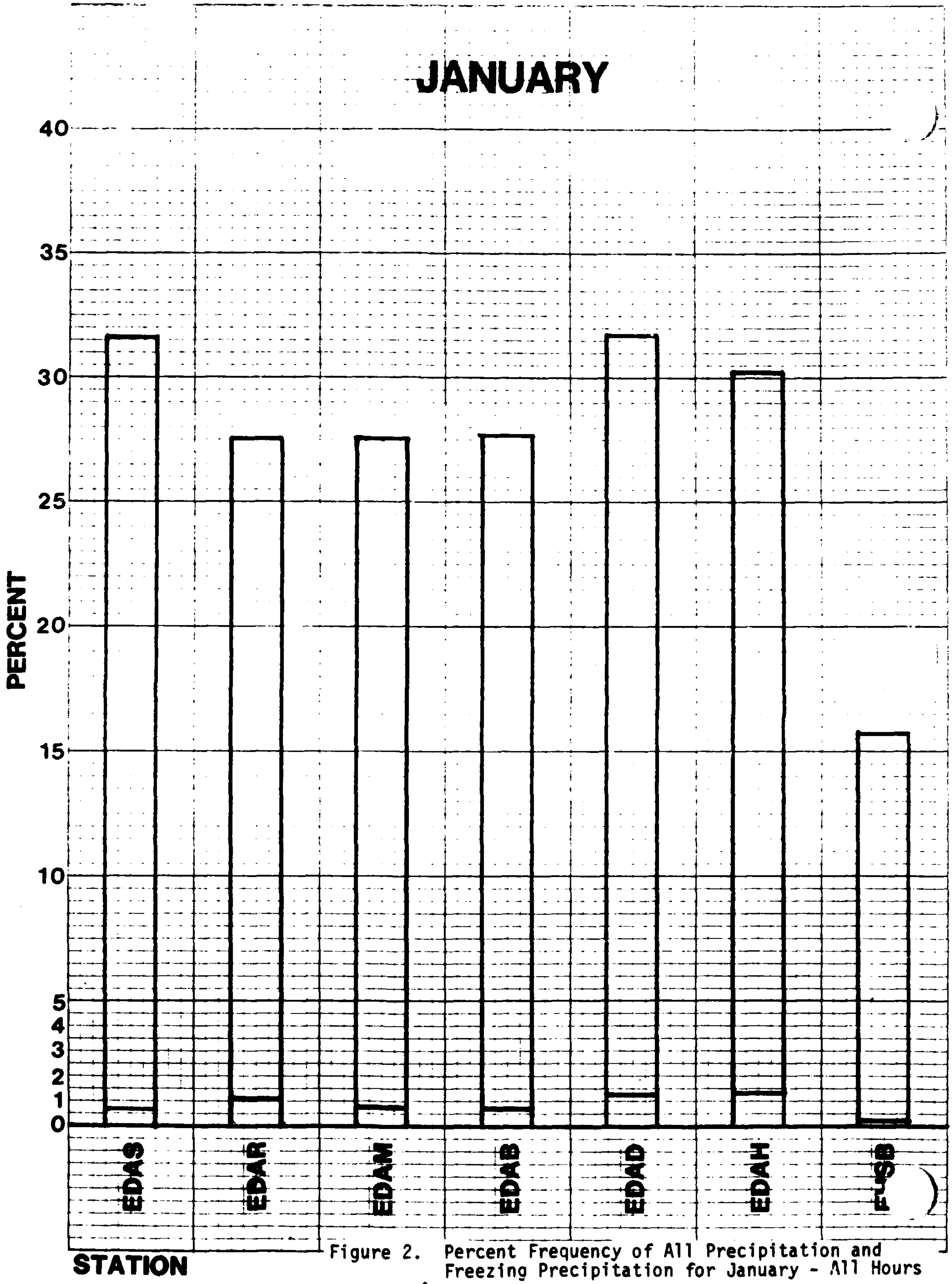

Figure 2. Percent Frequency of All Precipitation and Freezing Precipitation for January - All Hours

Table 1. Relative Frequency of Freezing Rain Events at Various Locations During the Day

TIME	RAMSTEIN	BITBURG	HAHN	SOESTERBERG
		DECEMBER		
00-02	0.9	1.0	0.8	0.0
03-05	1.0	0.4	1.0	0.2
06-08	1.0	0.7	1.8	0.8
09-11	0.8	1.0	0.8	0.4
12-14	0.3	0.5	1.0	0.0
15-17	0.3	0.7	1.1	0.0
18-10	0.5	0.7	1.3	0.2
21-23	0.5	1.3	1.6	0.1
		JANUARY		
00-02	0.4	0.5	1.6	1.0
03-05	1.0	0.8	1.0	1.1
06-08	1.2	0.8	1.4	1.3
09-11	1.1	1.4	1.4	1.1
12-14	1.8	1.0	1.3	0.4
15-17	1.5	0.6	1.3	0.4
18-20	1.1	0.6	1.6	0.6
21-23	0.8	0.7	1.4	0.7

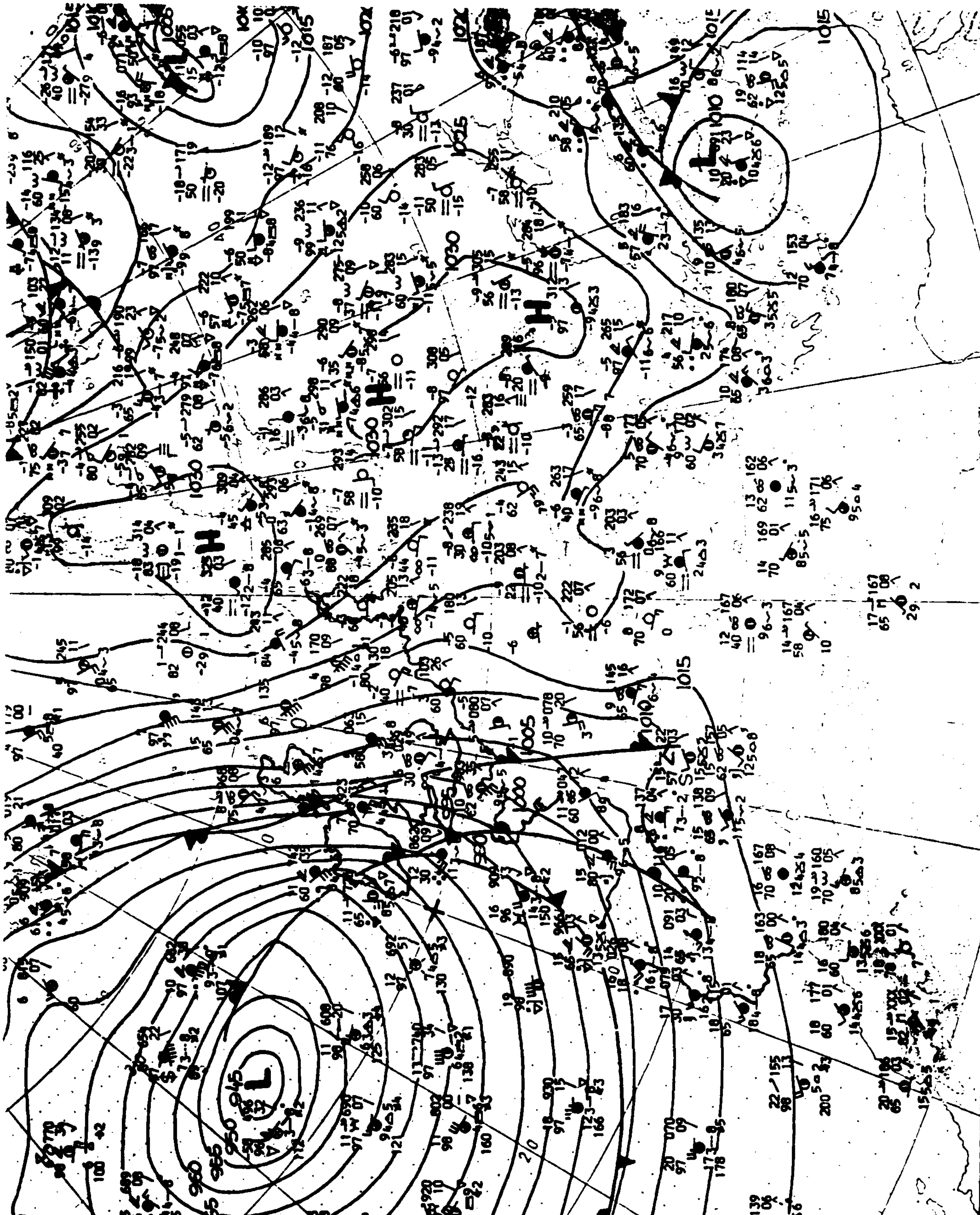

Figure 3. 7 Dec 78, 12Z - surface analysis

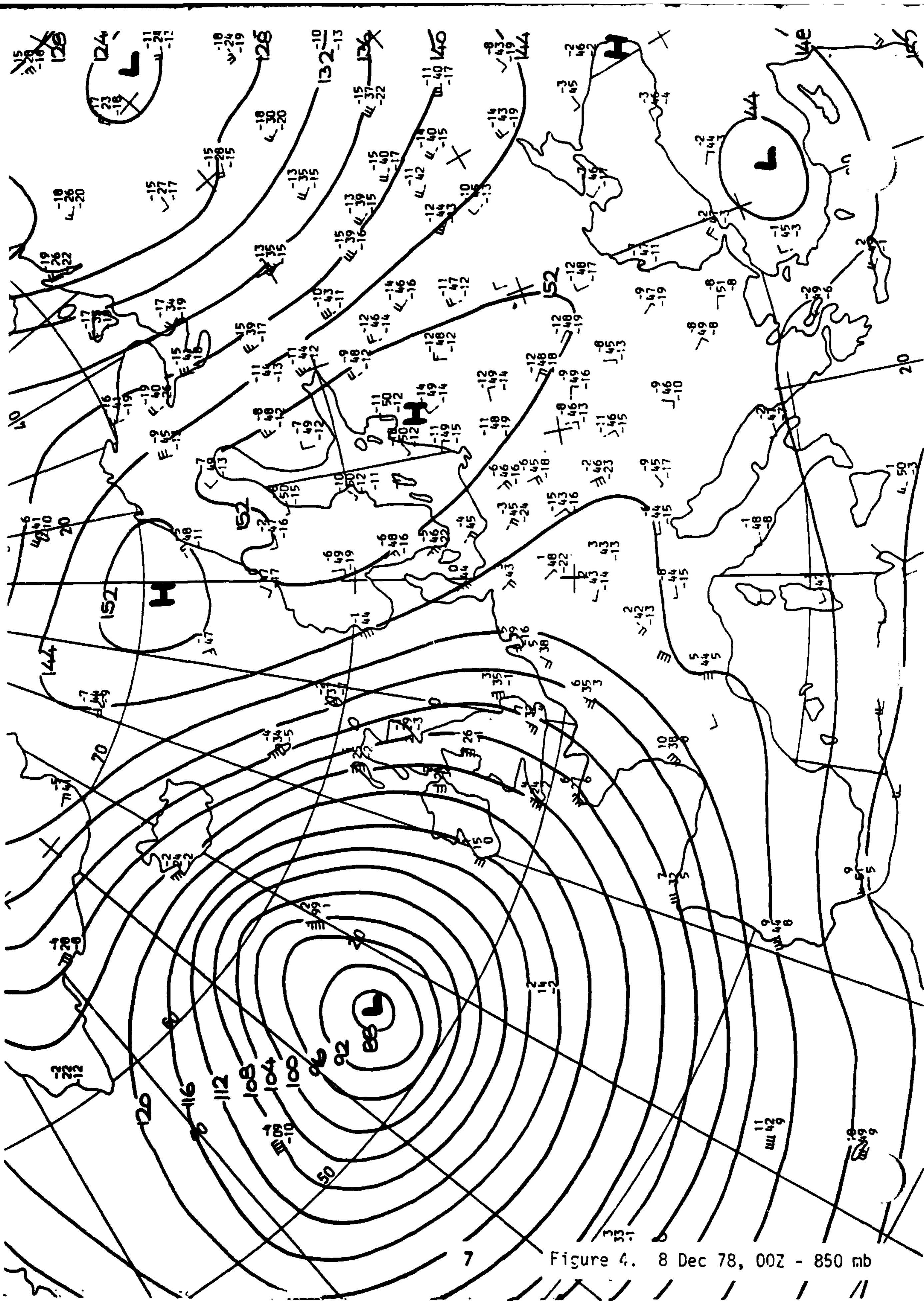

Figure 4. 8 Dec 78, 00Z - 850 mb

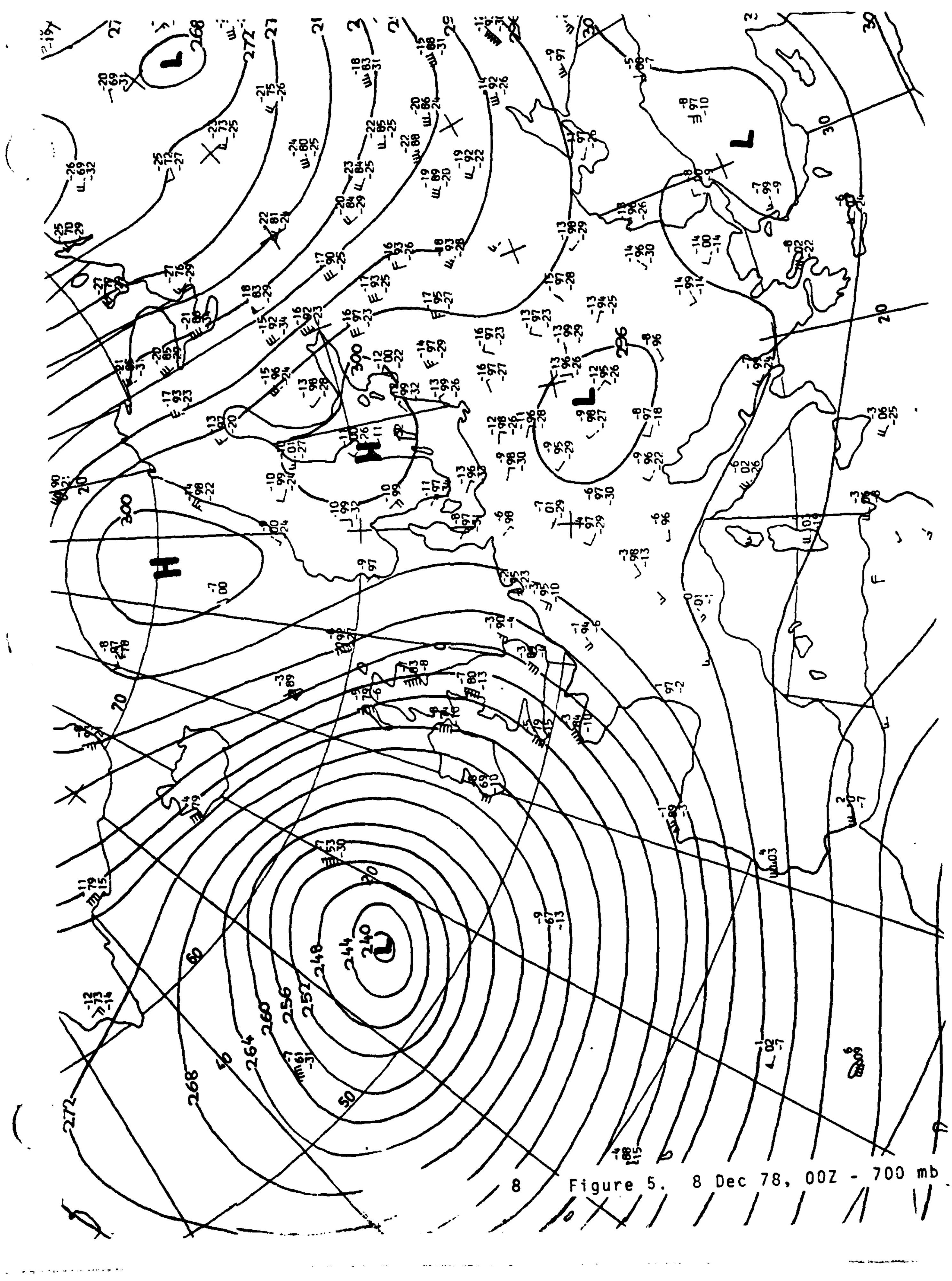

Figure 5. 8 Dec 78, 00Z - 700 mb

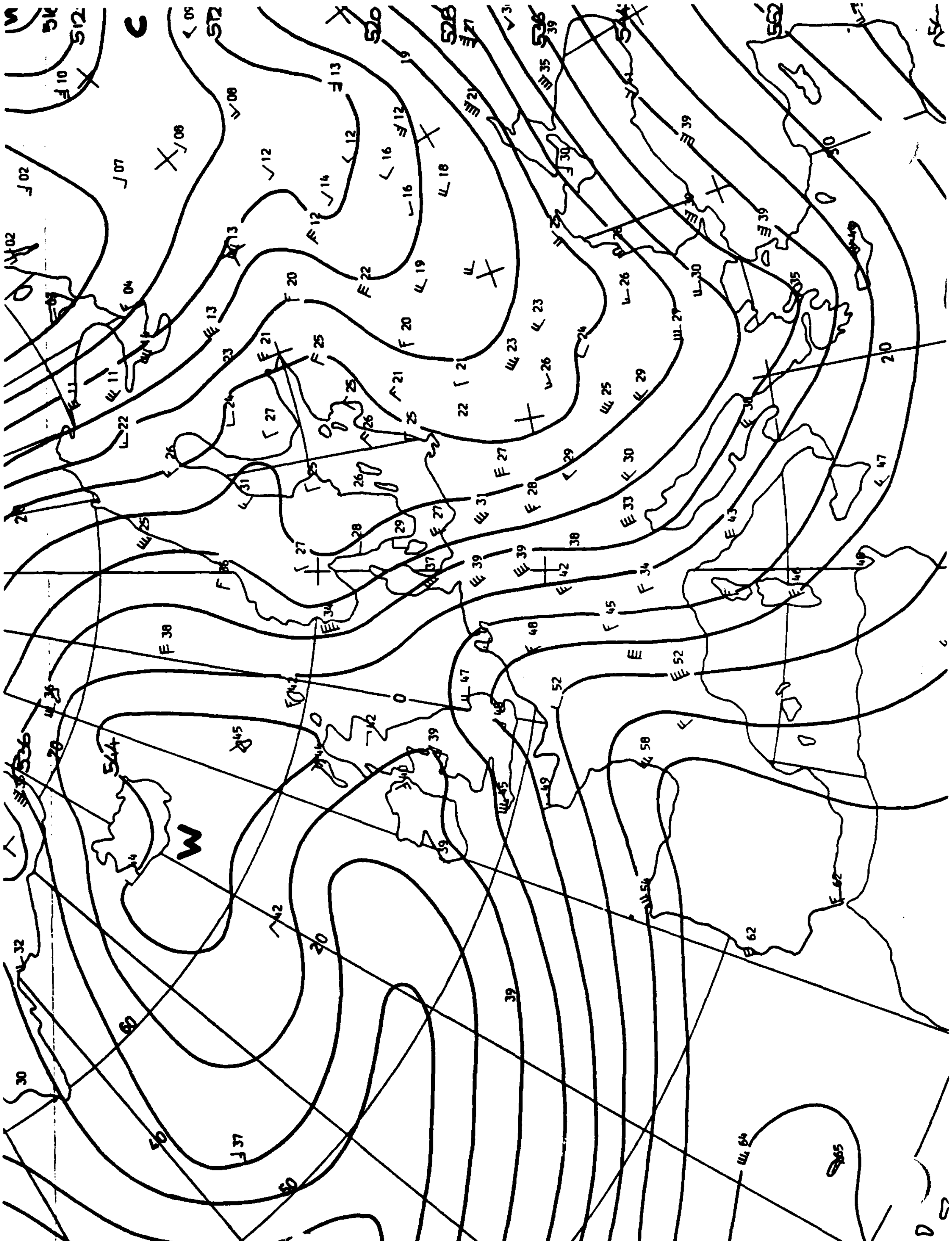

Figure 6. 8 Dec 78, 00Z - 1000-500 mb thicknes

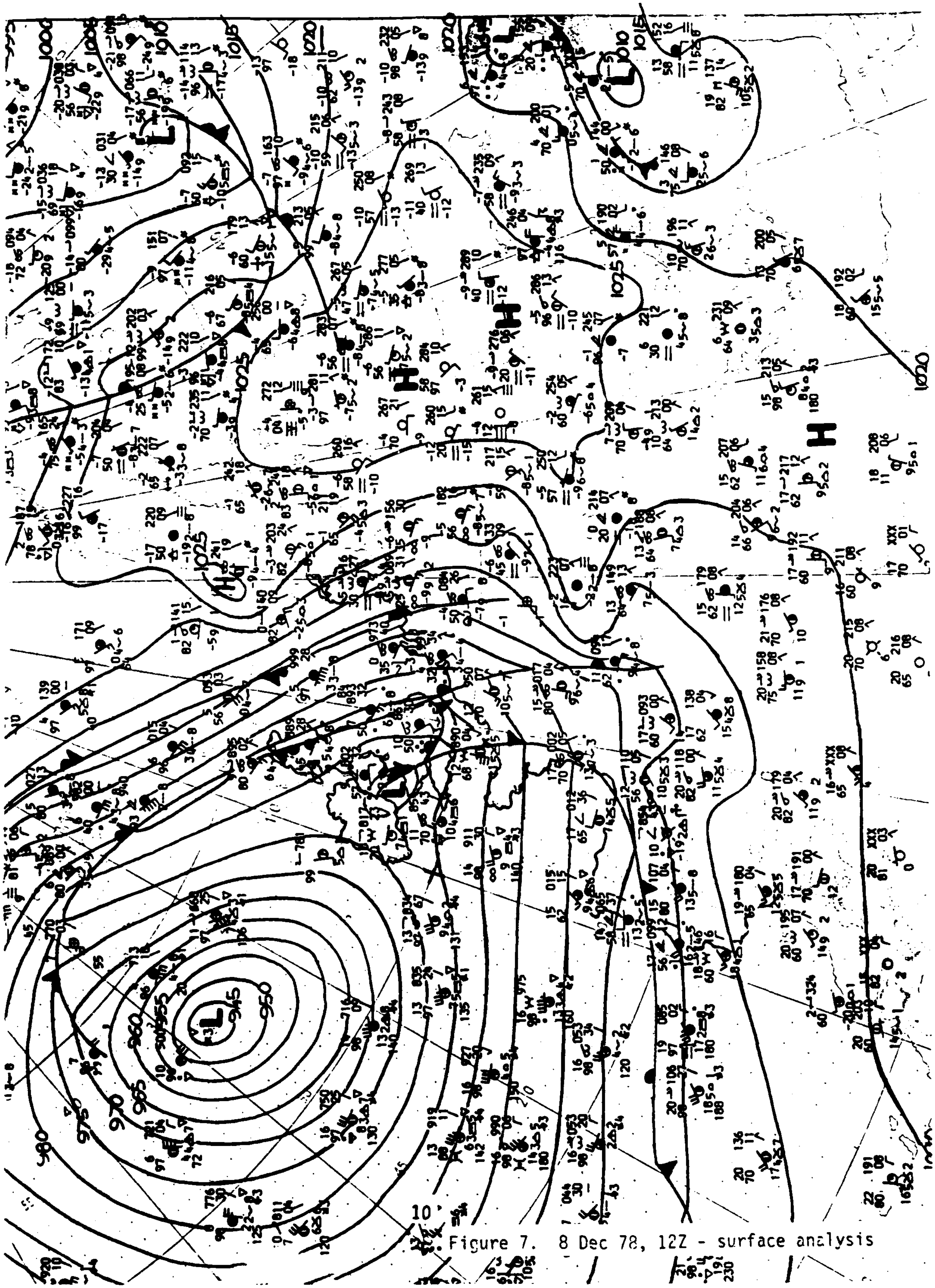

Figure 7. 8 Dec 78, 12Z - surface analysis

Table 2. Freezing rain climatology based on 24 freezing rain cases at Ramstein Air Base, Germany.

	#of cases	% freqency
a) Temperatures in ^{o}C		
1) 850mb $\geq 0^{o}C$	13	54
2) 850mb $\geq -2^{o}C$	20	83
3) 850mb $\geq -3^{o}C$	22	92
4) 700mb $\geq -6^{o}C$	13	54
5) 700mb $\geq -7^{o}C$	15	63
6) 700mb $\geq -9^{o}C$	20	83
b) Thickness		
1) Height $\geq$ 5400gpm	12	50
2) height $\geq$ 5350gpm	21	88
3) height $\geq$ 5330gpm	21	88
c) Combined parameters		
1) $T_{850} \geq -2^{o}C$ $T_{700} \geq -9^{o}C$	22	92
2) $T_{850} \geq -2^{o}C$ $T_{700} \geq -7^{o}C$	22	92
3) $T_{850} \geq -2^{o}C$ $T_{700} \geq -6^{o}C$	22	92

CHAPTER 2

Case Studies

1. The freezing precipitation climatology described in Chapter 1 gives a general orientation on the interacting physical parameters. This may lead to the false conclusion that freezing precipitation only occurs when warm fronts push eastward from France into Germany. Such is not the case. Indeed, there are many unanswered questions. For instance:

a. How dependent is freezing precipitation on wind direction?

b. Is freezing precipitation dependent on the orientation of the front (north-south, northwest-southeast, etc.)?

c. Does freezing precipitation occur only if warm fronts arrive?

d. Does freezing precipitation always turn into rain? And, if not, when does it turn into snow?

e. Is freezing precipitation a morning phenomenon?

A definitive answer may not be possible but the following case studies should help answer these questions. A definite "yes" or "no" based on statistical climatology is impossible since such climatology does not exist. Furthermore, the climatology shown in Table 2 is based on occurrences at Ramstein AB and may not be fully applicable at other bases because of different elevation and terrain features.

2. The following case studies are ordered by subject (flow patterns and frontal configurations) and show some obvious as well as some not so obvious situations. All cases have brief comments and are presented to familiarize forecasters with the weather patterns. Not all cases, however, are obvious.

WARM AIR ADVECTION FROM THE SOUTHWEST

The following 2 cases represent situations where warm air intruded from the southwest. In these cases warm air off the Bay of Biscay overran the cold air in central Europe. This is regarded as the classical situation as mild and moist Atlantic air can invade central Europe relatively uninhibited by terrain. However, the first major mountain chain can cause the lowest parts of the warm air to slow down. The result is turbulent mixing digging downward from levels between 930 and 880 mb (dependent on elevation of the "blocking" terrain) thus creating a transition zone between the cold continental air and the mild Atlantic air. This transition zone forces European analysts to create secondary or tertiary warm fronts/occlusions. If the advection is from further south, i.e., from the Balearic Sea, the higher mountains to the south of central Europe inhibit advection of warm air into levels lower than 900 mb. Often, there is already mixing aloft with continental air resulting in a slight cooling of the incoming warmer air.

CASE 1. 23-24 December 1978. The surface analysis from 23 Dec 78, 12Z (fig 8) shows a closed low southwest of the British Isles, with a warm front along the west coast of France and a cold front between the Irish Sea and the northwestern tip of Spain (Cape Finisterre). Unlike the 3 Dec 78 example in Chapter 1, there is no strong high pressure over central Europe. Instead, the high is displaced far to the southeast over the Ukraine. Surface temperatures in Germany and eastern France are below freezing. At 850 mb on 24 Dec, 12Z (fig 9), above freezing temperatures are pushing northeastward over France and have reached the Netherlands and southwest Germany. Warm air advection at 700 mb (fig 10) is raising temperatures to values warmer than -7°C. The 1000-500 mb thickness (fig 11) is greater than 5390 gpm and 5404 gpm at De Bilt and over France, respectively. The surface analysis from 24 Dec 78 (fig 12) shows freezing precipitation at Rhein-Main with weak winds from the northeast. Notice the difference in frontal analysis between 23 and 24 December. An additional occlusion extends from the Alps towards the North Sea and northwestward into Scotland. This occlusion is causing widespread freezing precipitation in southwest Germany but is unable to displace the cold air at the surface. The approaching warm front is warming the temperatures to above freezing but mixing fog and melting snow is causing poor visibilities. A 35 knot southwesterly wind at 850 mb is unable to break the inversion. Strong winds associated with the cold front over France provided the warming throughout the Netherlands and Belgium before the rain began.

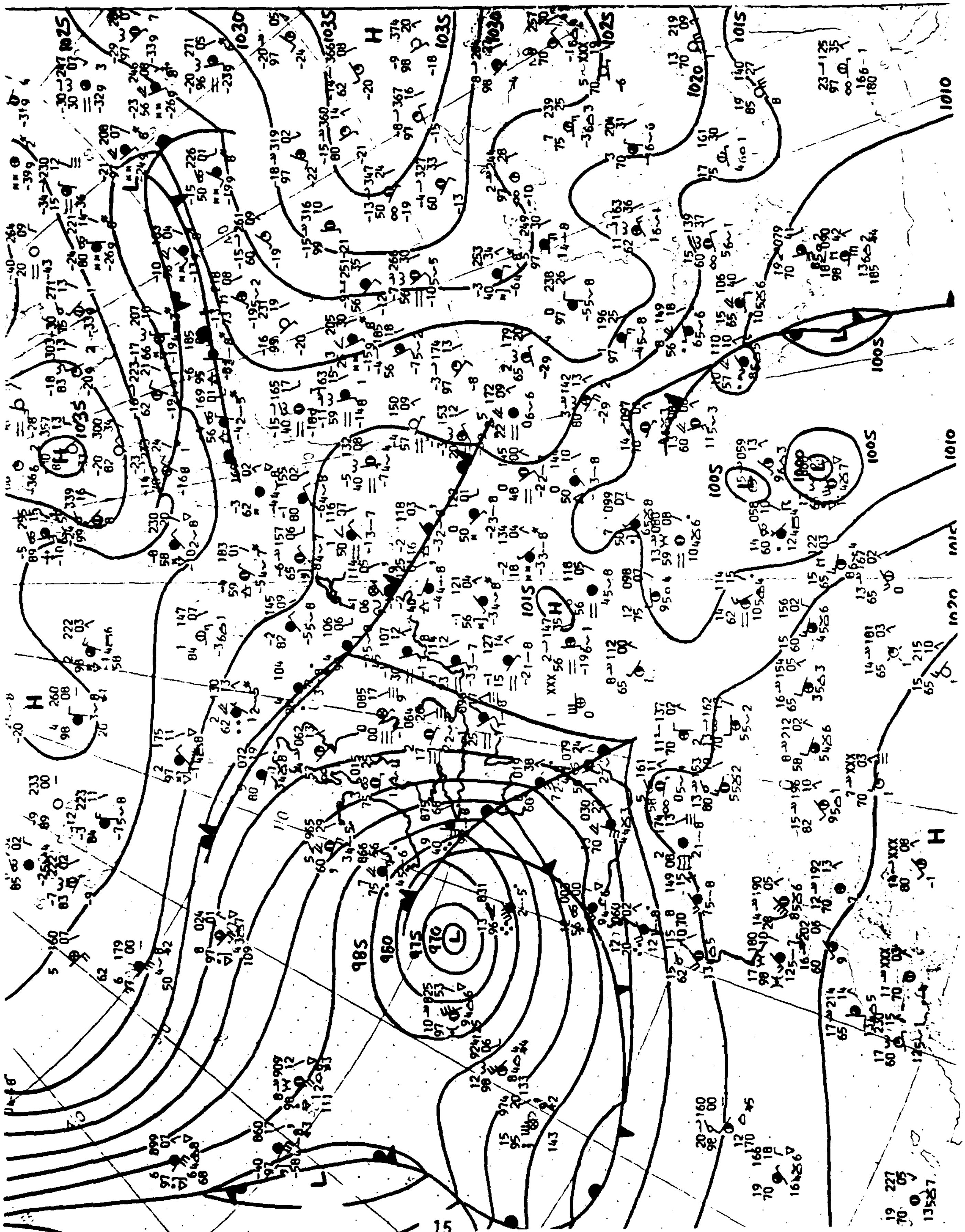

Figure 8. 23 Dec 78, 12Z - surface analysis

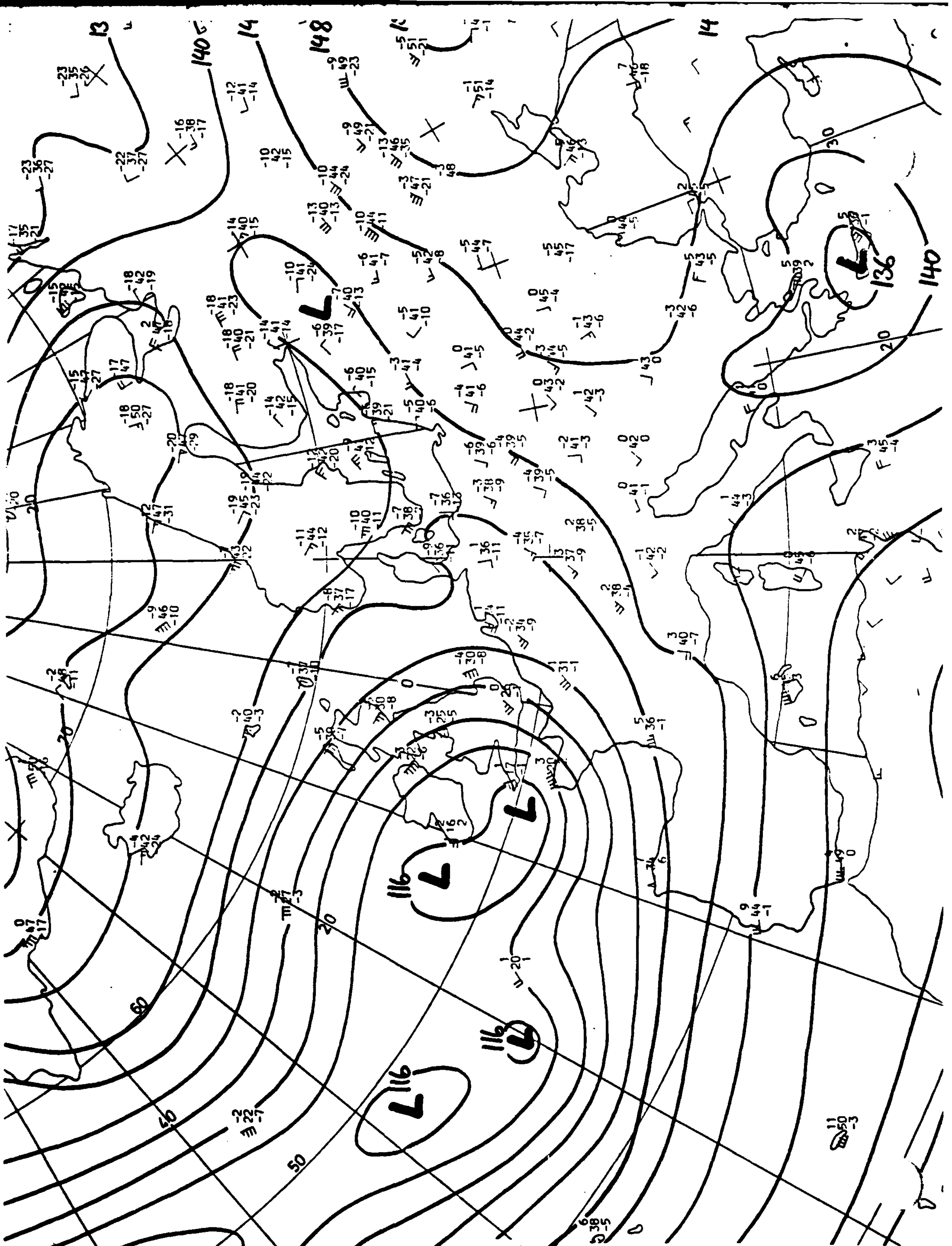

Figure 9. 24 Dec 78, 00Z - 850 mb

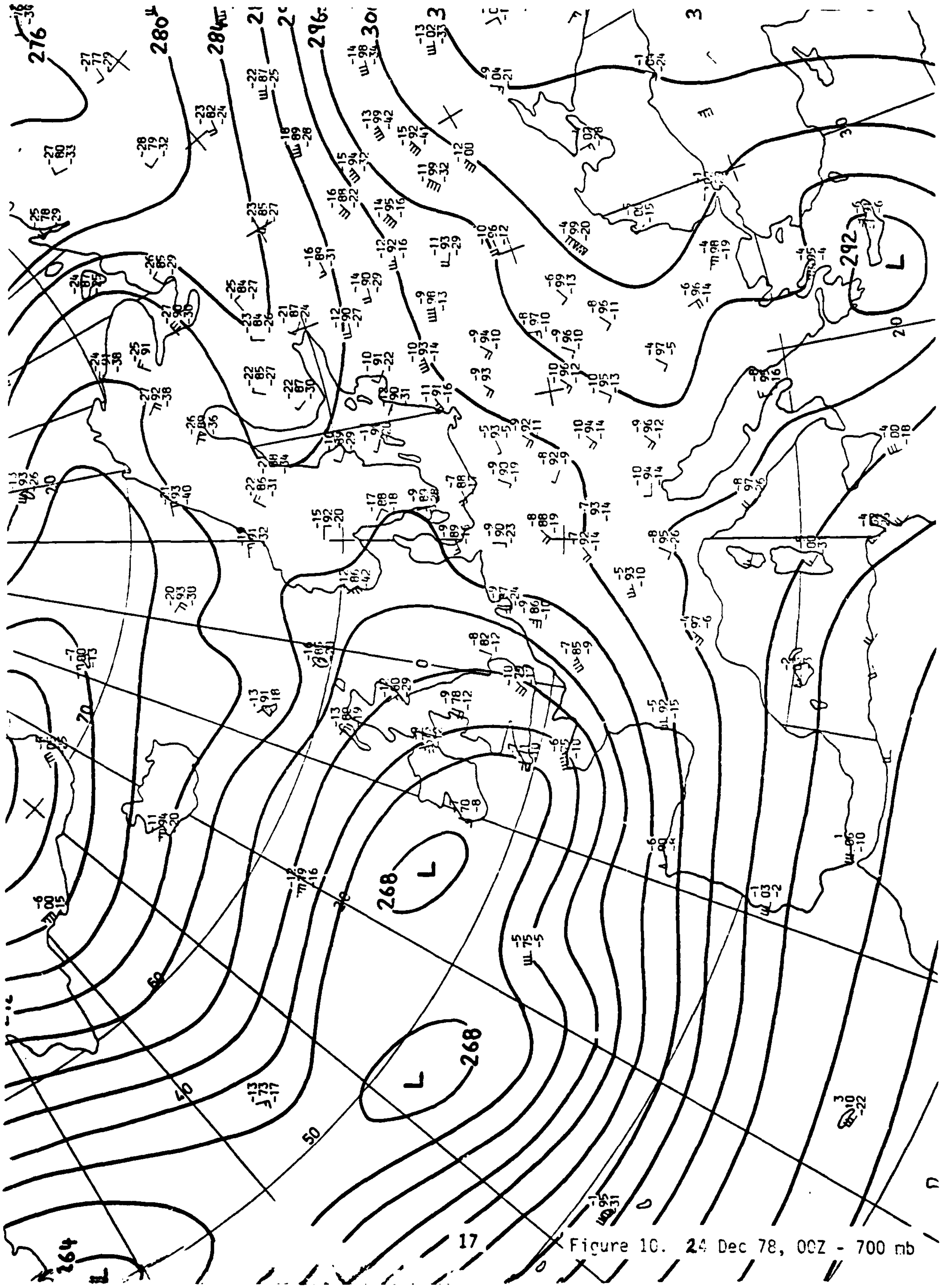

Figure 10. 24 Dec 78, 00Z - 700 mb

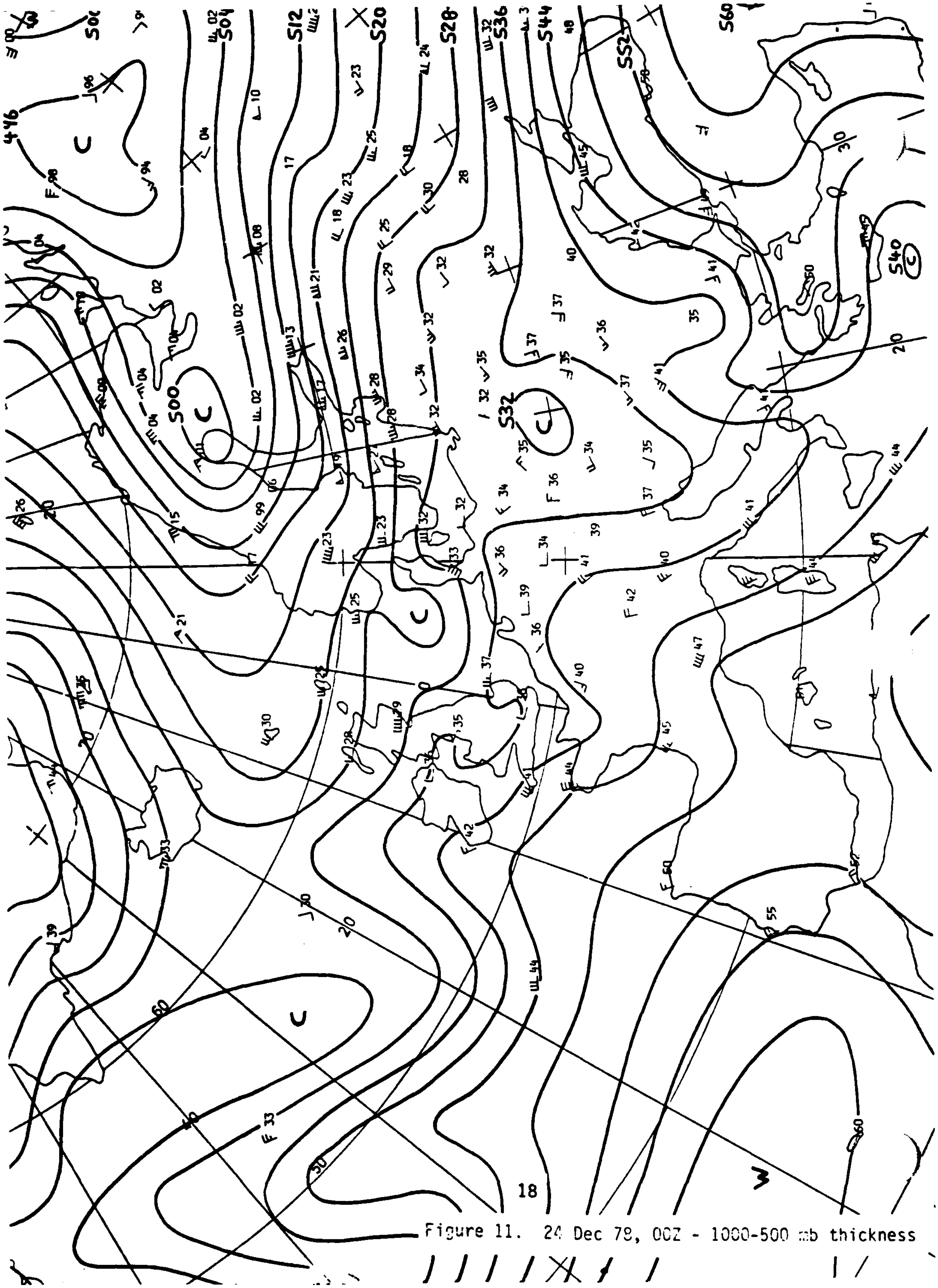

Figure 11. 24 Dec 78, 00Z - 1000-500 mb thickness

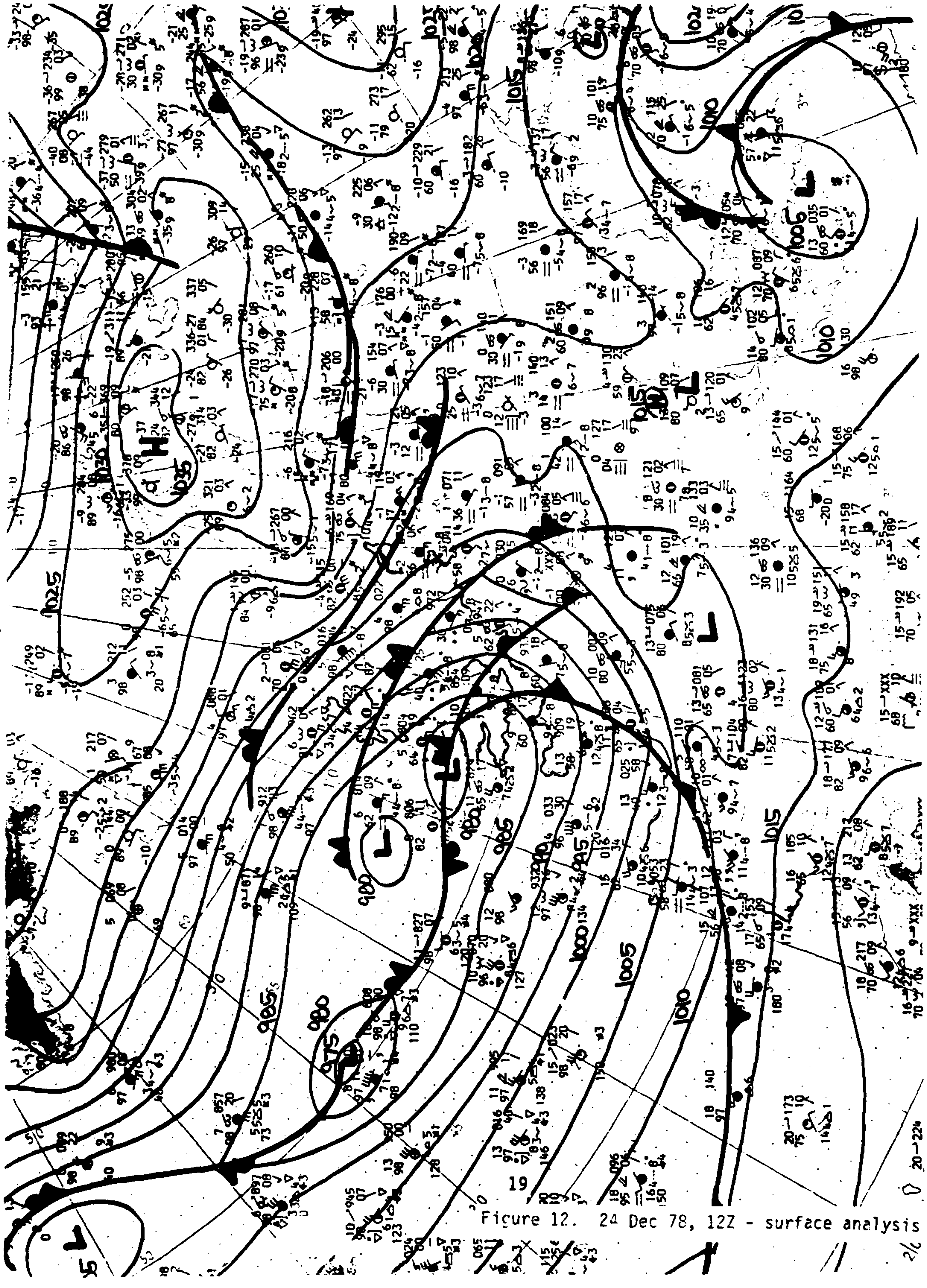

Figure 12. 24 Dec 78, 12Z - surface analysis

CASE 2. 28 December 1981. The surface analysis (fig 13) shows a deep low west and southwest of Ireland. The configuration is similar to the case shown in Chapter 1 but here the storm system is displaced further south. This results in southerly cyclonic flow over central Europe, with southwest to south flow even at 850 mb (fig 14). Though this direction indicates warm air advection, temperatures are relatively cold, between $-1^{o}C$ and $-3^{o}C$ over southern Germany and near freezing over France. Temperatures at 700 mb (fig 15) are also on the cold side, with $-10^{o}C$ over Germany warming to $-7^{o}C$ over France. Table 2 should work by using the and/or condition for the 850-700 mb temperature. Ramstein and Zweibruecken had some freezing precipitation but Rhein-Main had snow. Working with the thickness chart (1000-500 mb, fig 16) yields marginal thresholds (around 5340 gpm, which is low enough to forecast snow). However, the fact that Rhein-Main received snow is a function of the height of the Taunus mountains north of Frankfurt. The southerly flow at 850 mb has pushed the cold air against the Taunus mountains and forced it to flow over or around the mountains. Ramstein and Zweibruecken have the downslope effect off the Vosges west of the Black Forest which creates a warm tongue somewhere between the surface and the 850 mb level. Increasing warm air advection increased the temperature at all levels, but the warm fronts following this event (not shown here), were unable to remove the cold air at the surface. Precipitation was meager due to downslope effect from the Massif Central and lack of positive vorticity advection. Bottom line: Think terrain.

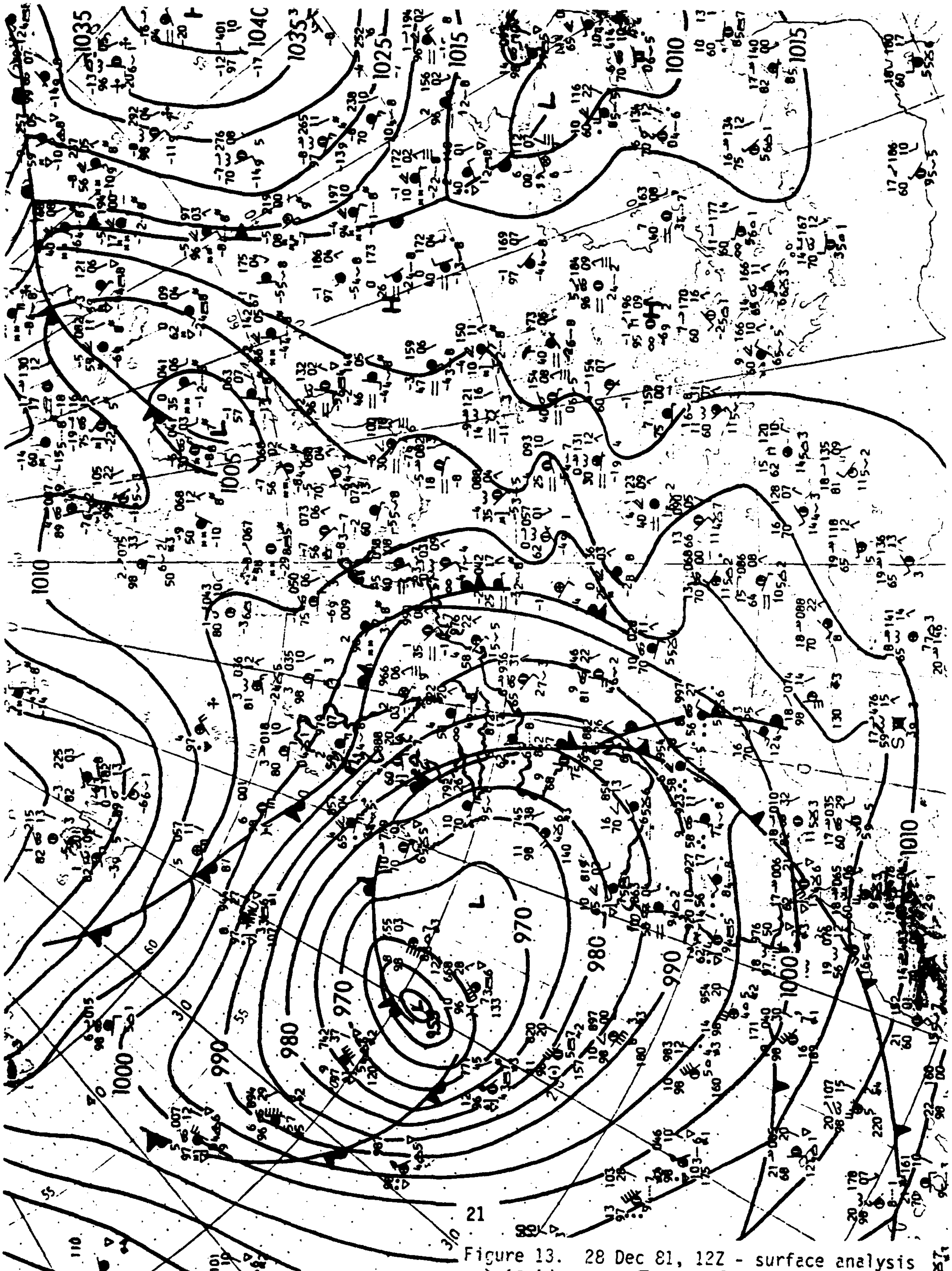

Figure 13. 28 Dec 81, 12Z - surface analysis

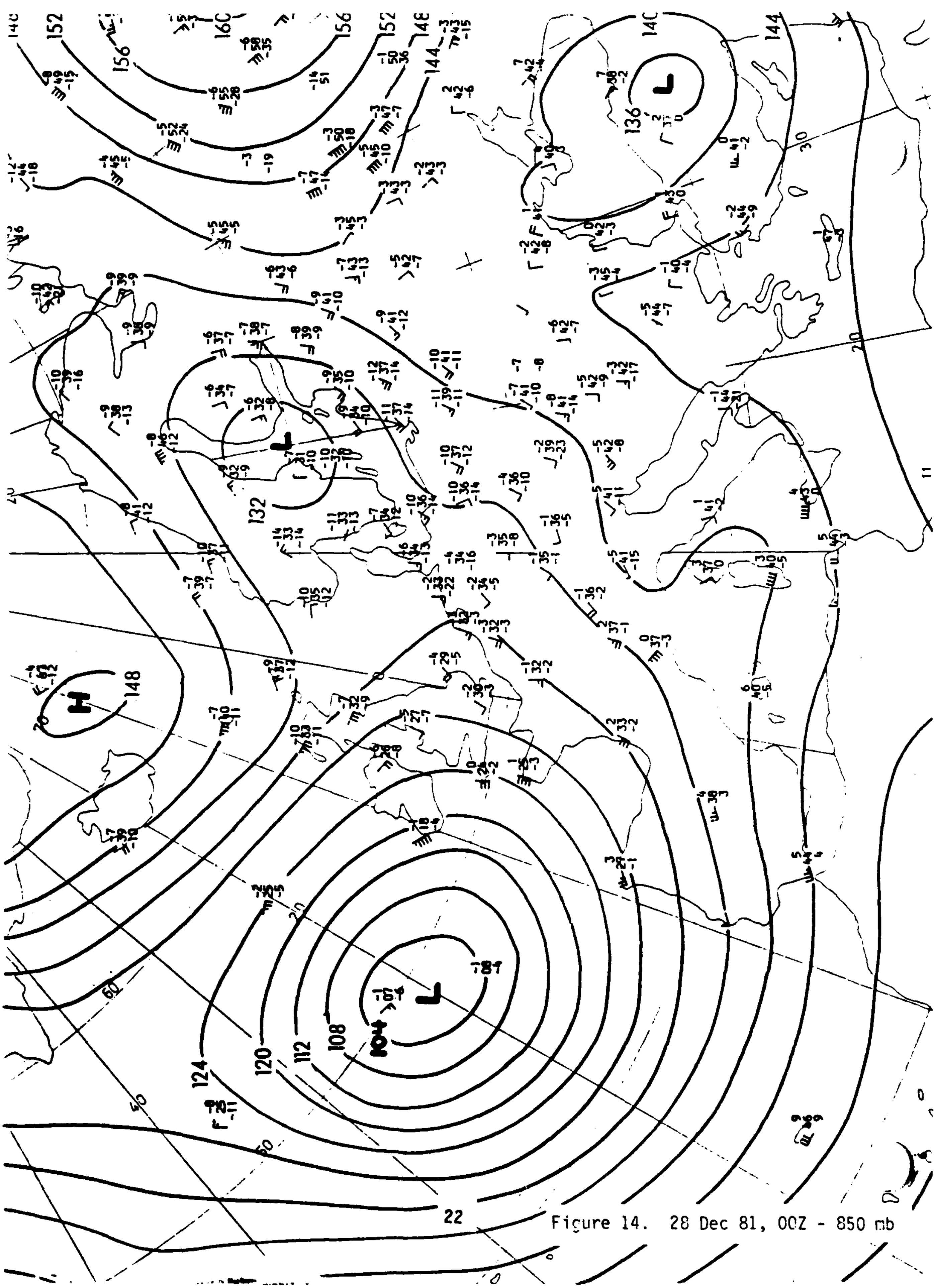

Figure 14. 28 Dec 81, 00Z - 850 mb

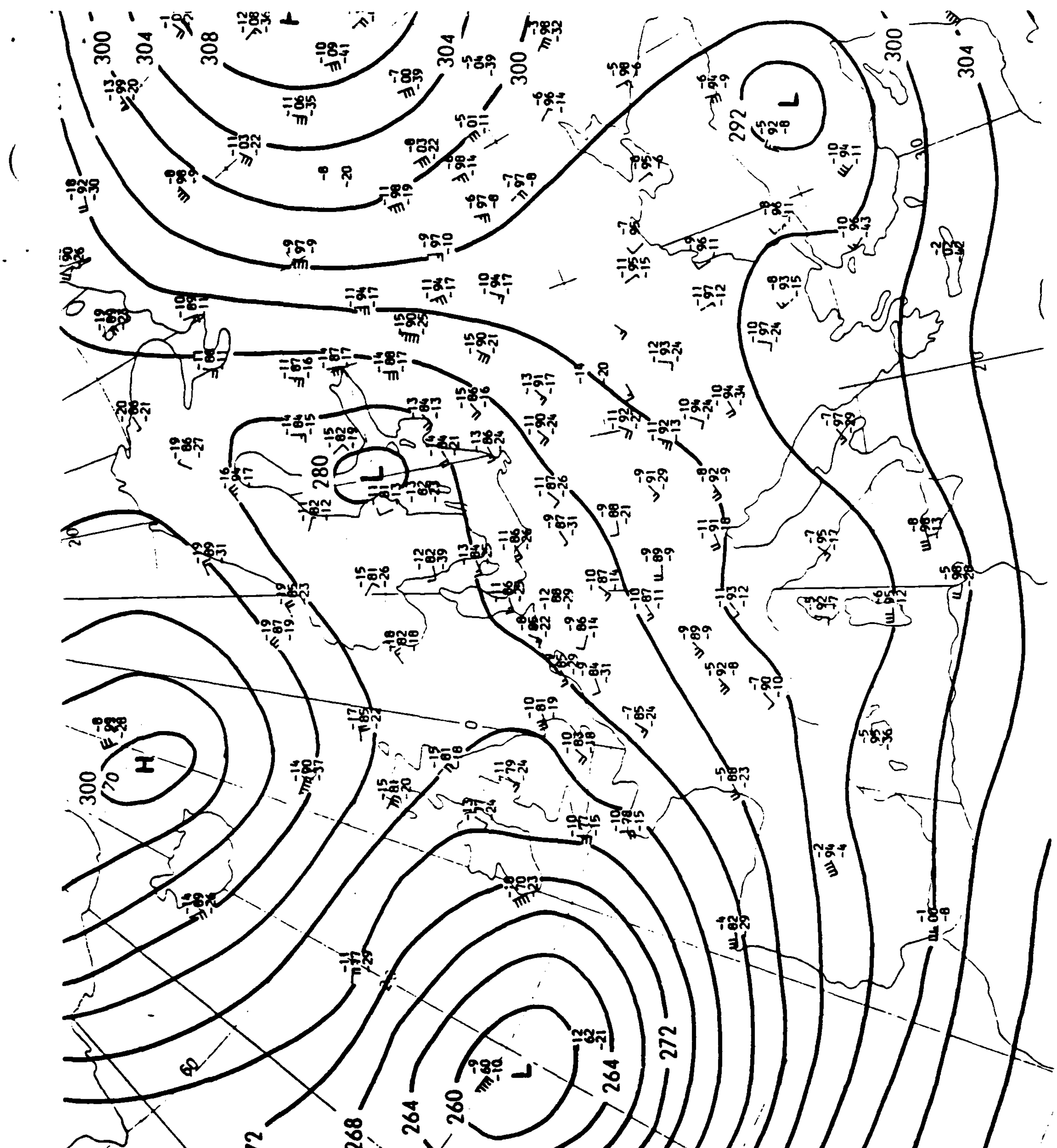

Figure 15. 28 Dec 81, 00Z - 700 mb

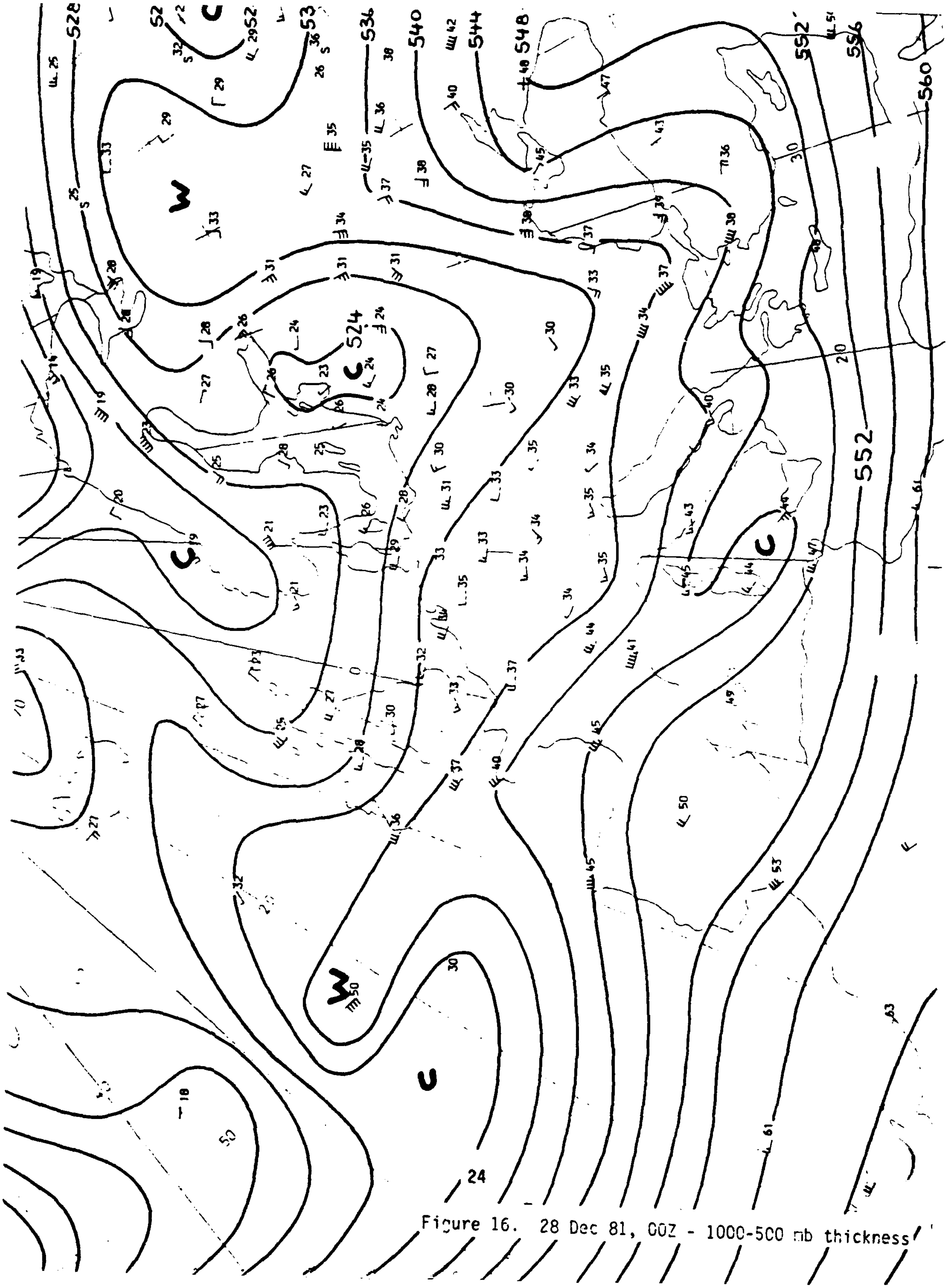

Figure 16. 28 Dec 81, 00Z - 1000-500 mb thickness

WARM AIR ADVECTION FROM THE WEST

Since westerly flow is most common in Europe, these are often cases when warm air from the west, i.e., from the Irish Sea or the English Channel, enter central Europe and replace cold air. This can be in association with intense storm systems. However cold air aloft may quickly run into the warm air and it is sometimes a matter of good timing whether the warm sector can reach parts of central Europe with full strength. Also, with a strong jet arriving at the western fringes of central Europe (Benelux) the question arises whether increasing upper air winds can create enough turbulent mixing to remove the cold dome at the surface before the precipitation sets in.

CASE 3. 24-25 November 1983. The surface analysis from 24 Nov 83, 12Z (fig 17) shows a strong high over southeastern Europe with a ridge over the Alps and southern Germany. A complex North Atlantic storm system is influencing northwestern Europe. A warm front over France is moving eastward and occluding. Temperatures are well above freezing north of the Eifels, but below freezing south and east of them. At 850 mb, (fig 18) the flow is westerly, and temperatures are above freezing. Though this configuration is 12 hours after the surface analysis, the influence of strong winds (30-35 knots) is evident ahead of and behind the front. There is no change in temperature and wind at 700 mb (fig 19), which is warmer than -7°C. The question is, "is it too windy for freezing rain?" At 850 mb, 35 knot winds from the west should be strong enough to destroy the temperature inversion before the rain begins. Apparently, they weren't, since Ramstein had freezing precipitation which turned into drizzle and fog. Additional information is in the 25 Nov 83 12Z surface analysis (fig 21) which is several hours after the event. By that time, Rhein-Main is still considerably colder (3°C) than northern Germany (6-7°C) or Bavaria (10°C) which is enjoying a weak foehn effect. At Rhein-Main, the flow is neutral (parallel to the Taunus mountains) but the deep Rhein-Main basin still contains some cold air which is mixing with the incoming warmer air from the Atlantic. At Ramstein, the westerly flow is weak upslope, hence the cold air in the basin is pushed against the Pfaelzerwald and is hard to remove. Consequently, turbulent mixing resulted in fog and slow warming in sheltered valleys or basins.

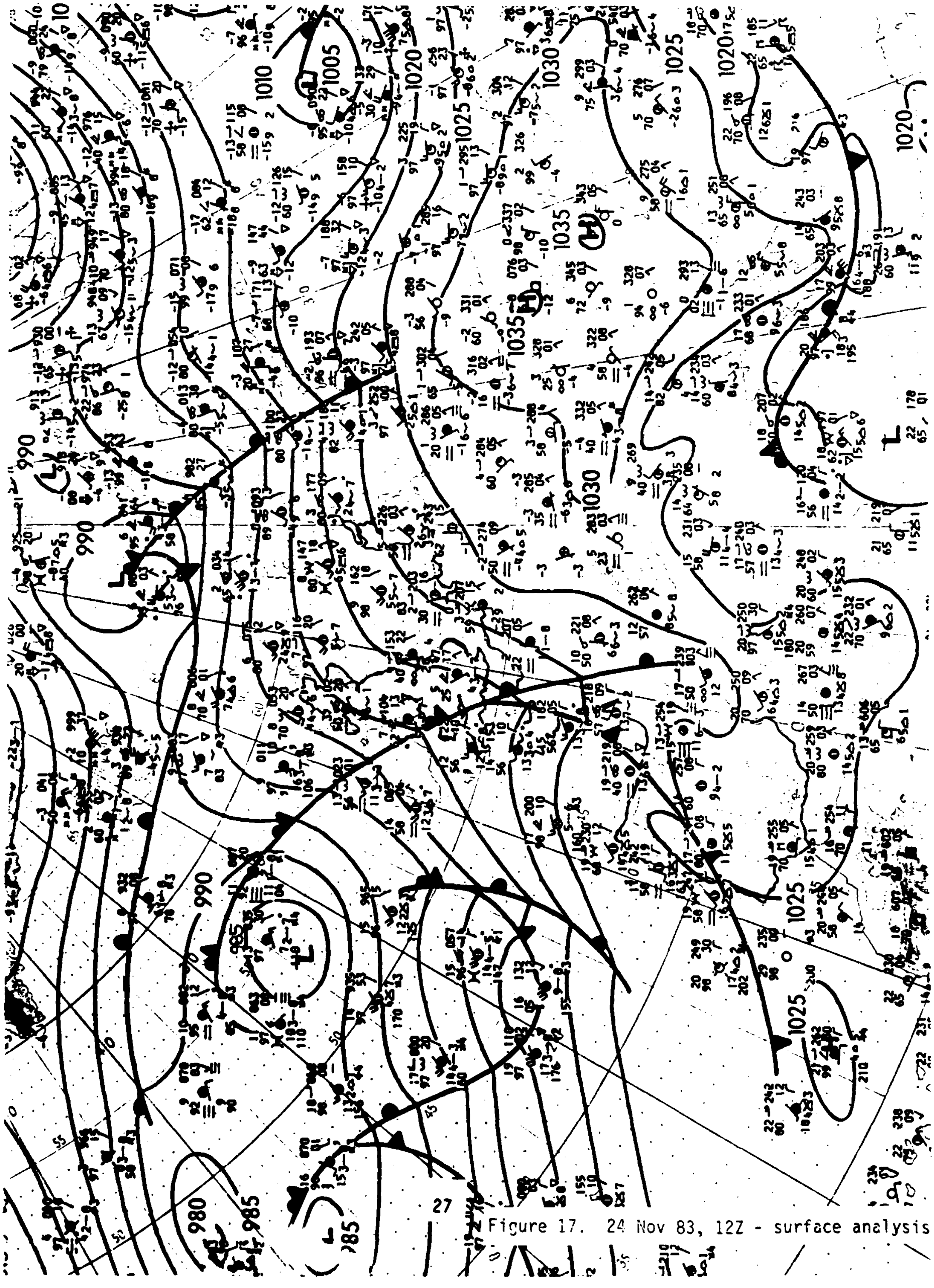

Figure 17. 24 Nov 83, 12Z - surface analysis

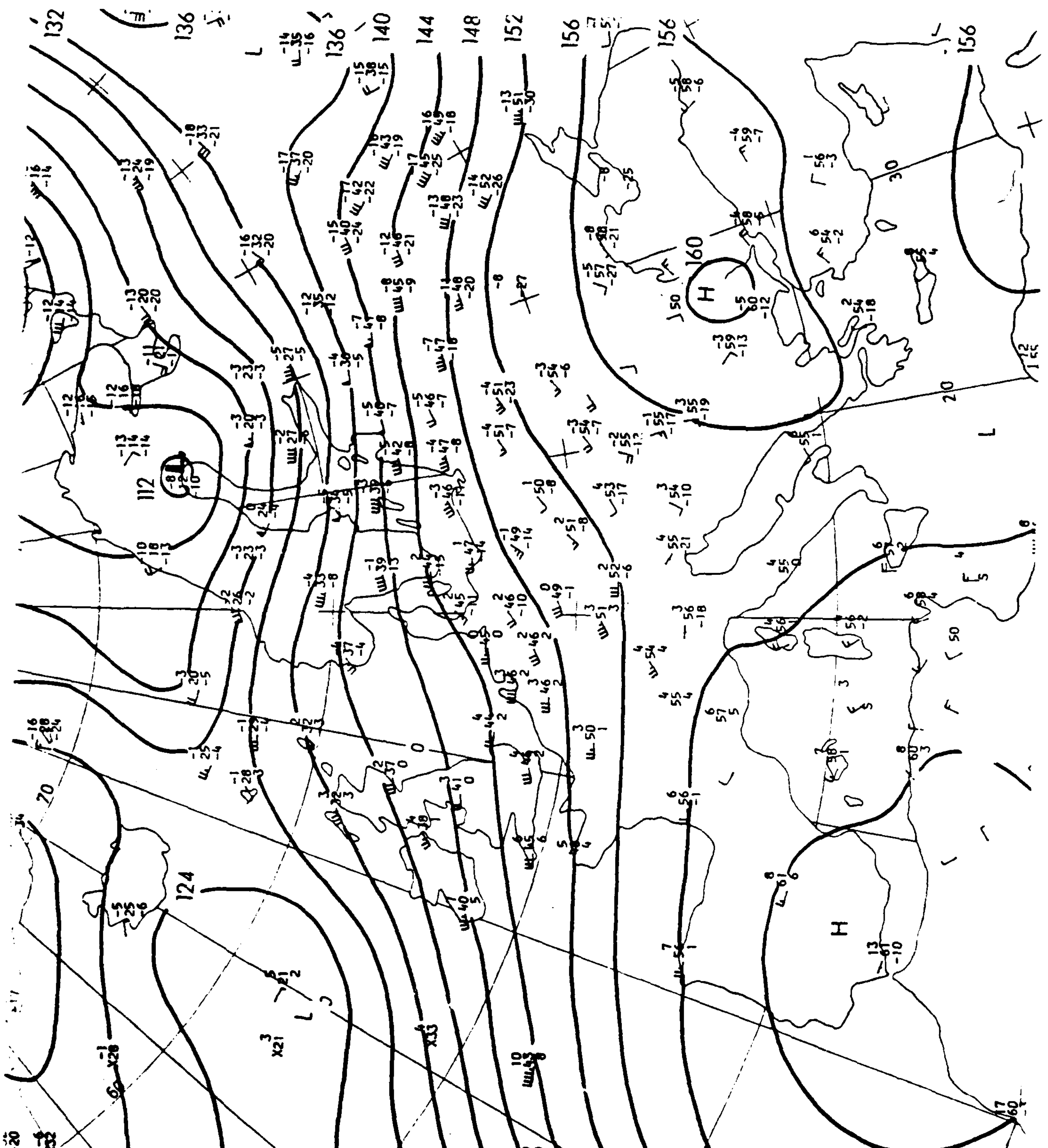

Figure 18. 25 Nov 83, 00Z - 850 mb

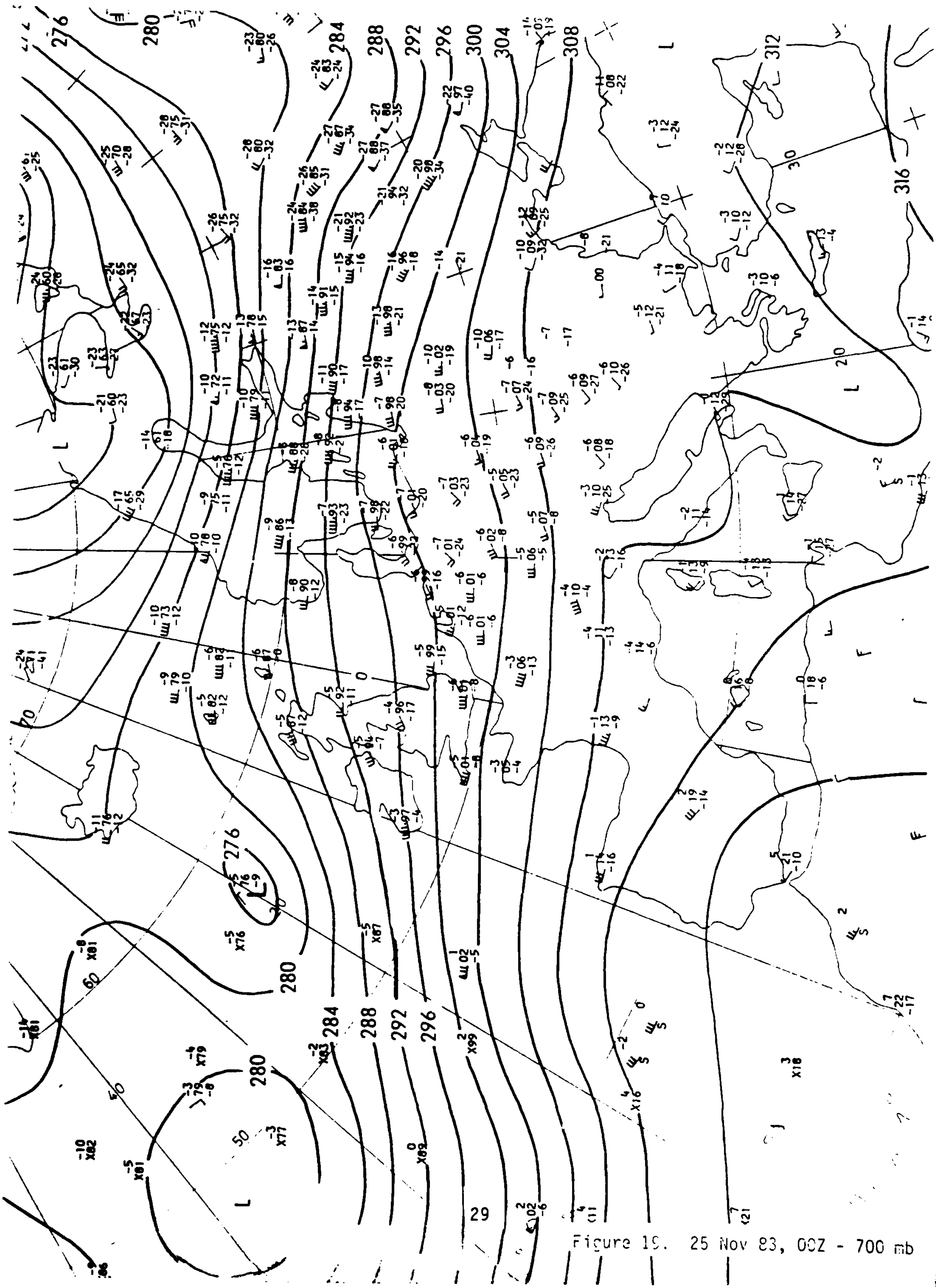

Figure 19. 25 Nov 83, 00Z - 700 mb

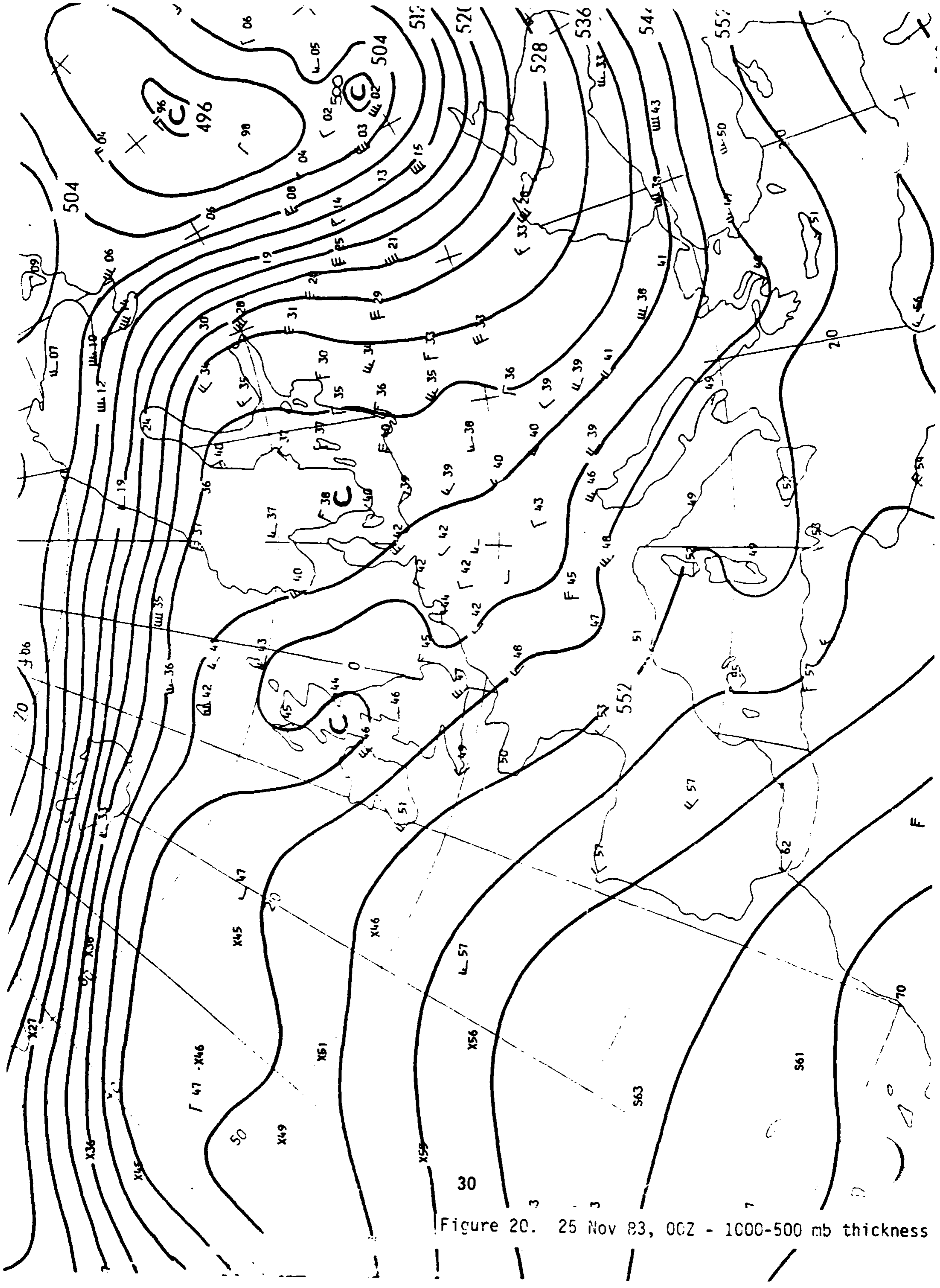

Figure 20. 25 Nov 83, 00Z - 1000-500 mb thickness

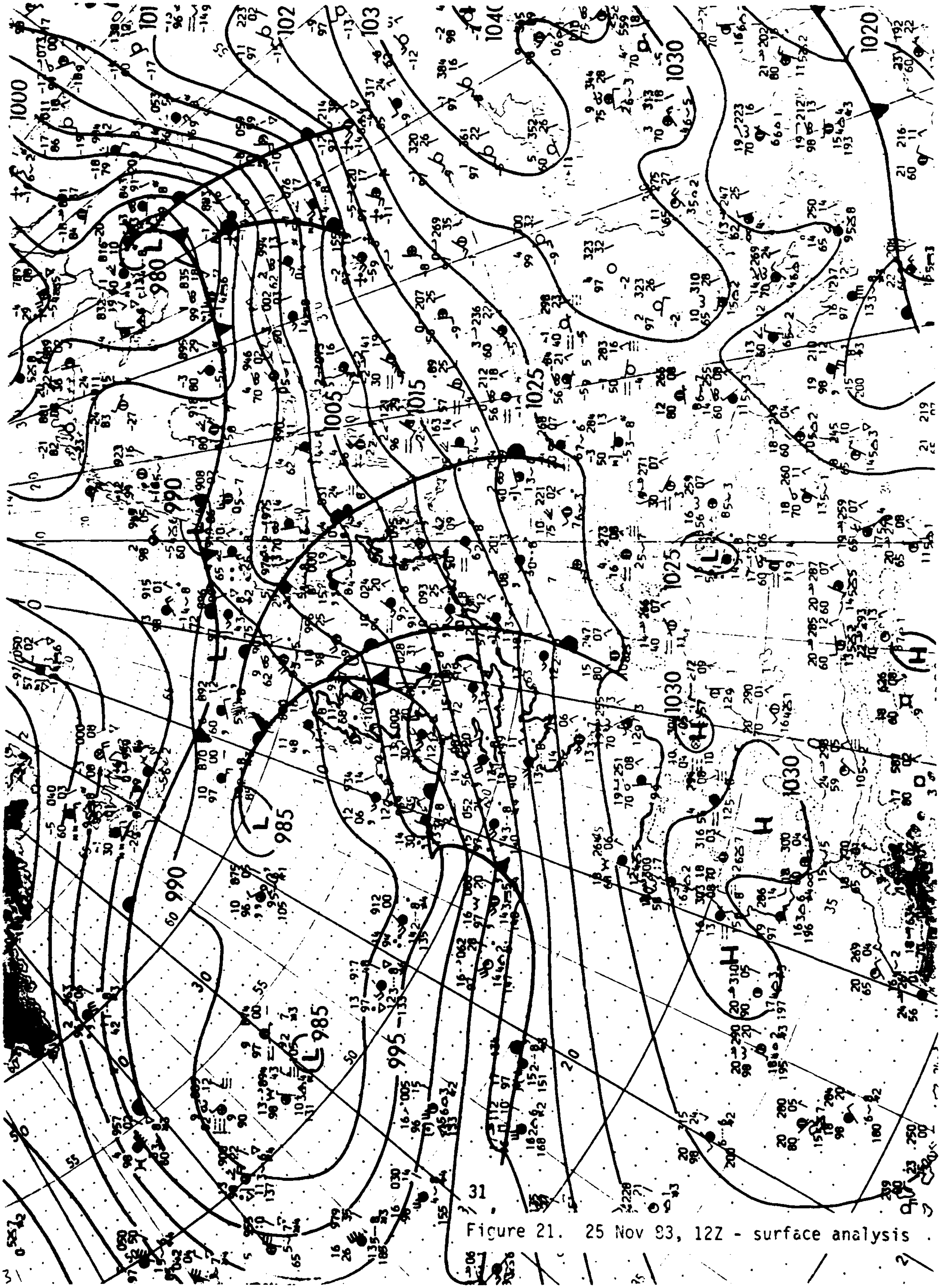

Figure 21. 25 Nov 83, 12Z - surface analysis

CASE 4. 1-2 January 1983. Again strong winds. The surface analysis on 1 Jan 83, 12Z (fig 22) shows an extended high pressure belt over the Mediterranean and a deep low between Iceland and Greenland. An elongated cold front running along the Norwegian Coast and curving westward over the U.K. is moving southeast i.e., it will enter Germany. Temperatures are below freezing over eastern France, southwestern Germany and parts of Belgium. The 850 mb chart, on 2 Jan 00Z (fig 23) shows strong westerly winds, 30-35 knots, and above freezing temperatures--no snow. But the flow is still weak in southern Germany. At 700 mb (fig 24), winds are strong over central Europe and temperatures are warmer than -7°C. The surface map on 2 Jan, 12Z (fig 26) clearly shows that the strong 850 mb winds did not replace the cold air at the surface; Rhein-Main has 1°C with weak southwesterly winds in the vicinity of the dissipating front. The reason: terrain and distance from the cyclonic activity weakened the front. (see case 3) Even in Belgium (toward the northwest) temperatures are considerably cooler (Brussels has 3°C) and mixing fog is reported.

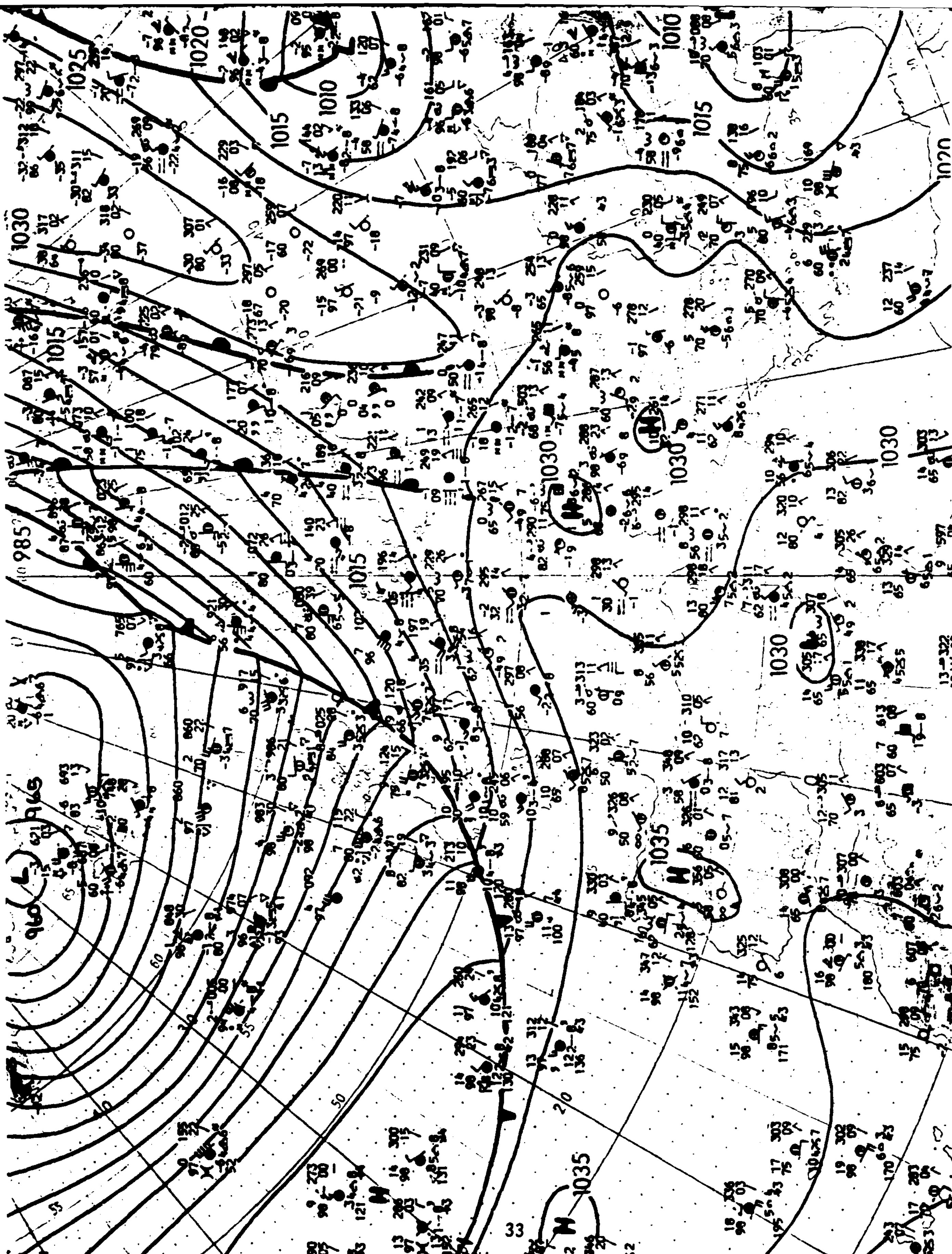

Figure 22. 2 Jan 83, 00Z - surface analysis

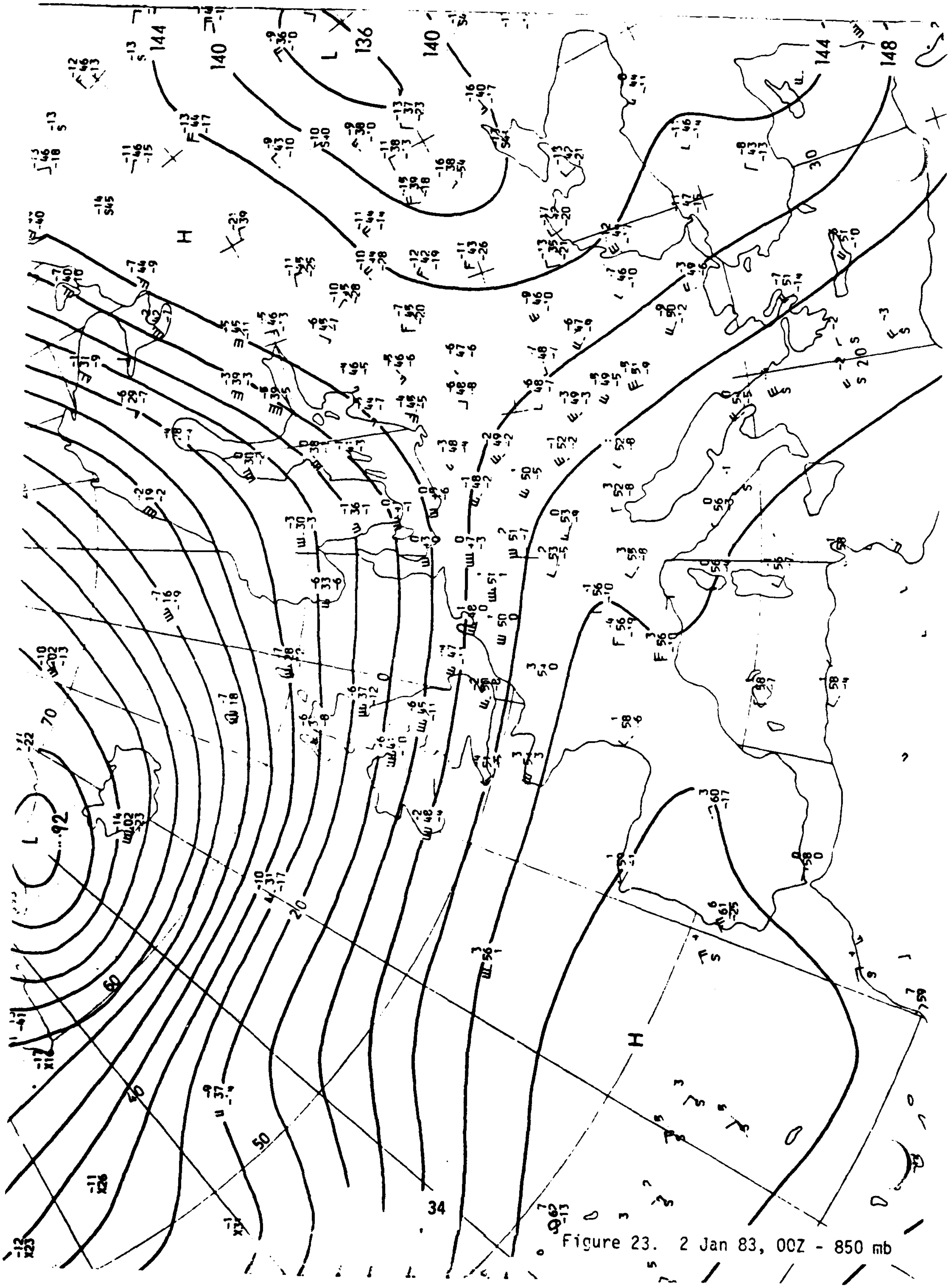

Figure 23. 2 Jan 83, 00Z - 850 mb

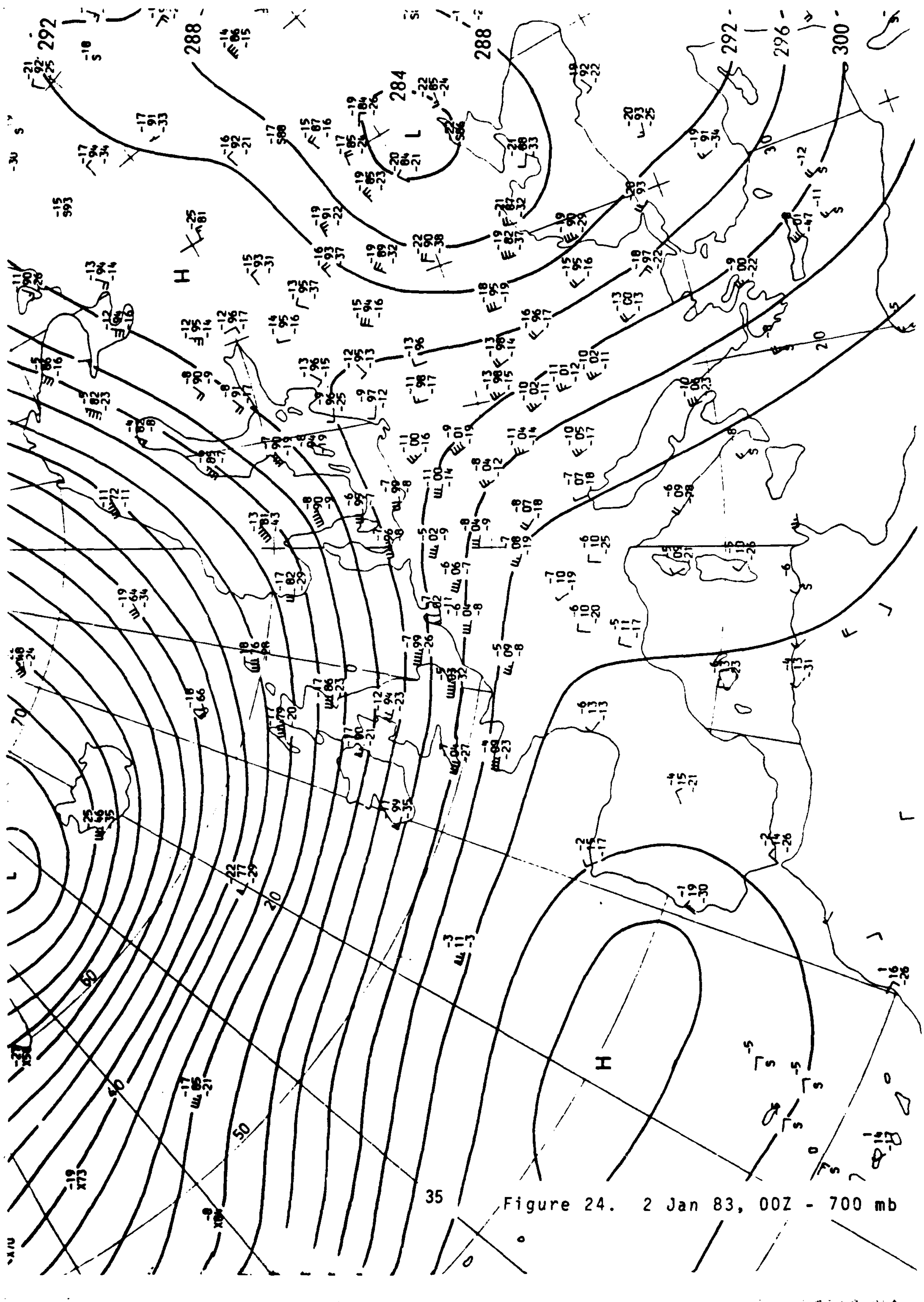

Figure 24. 2 Jan 83, 00Z - 700 mb

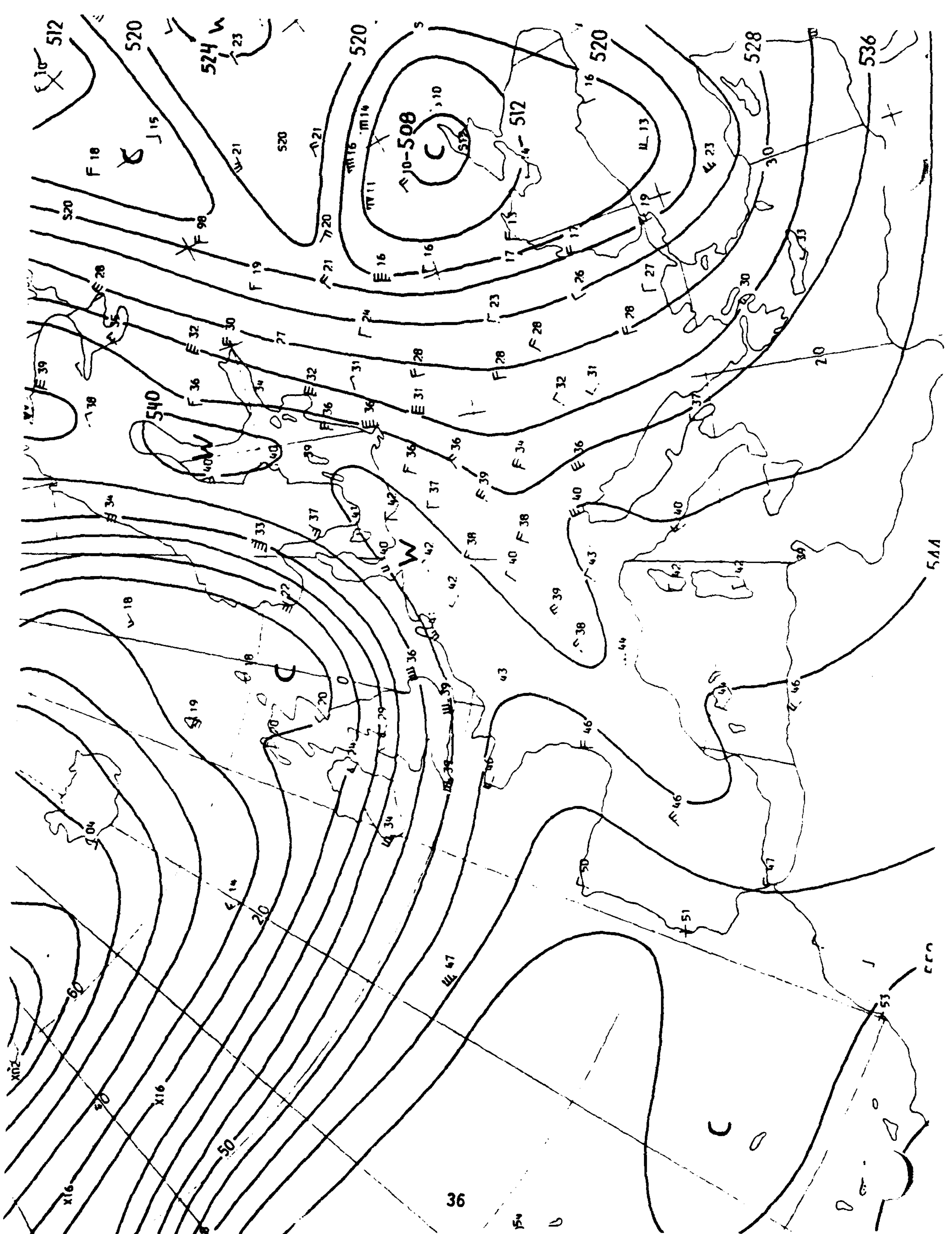

Figure 25. 2 Jan 83, 00Z - 1000-500 mb thickness

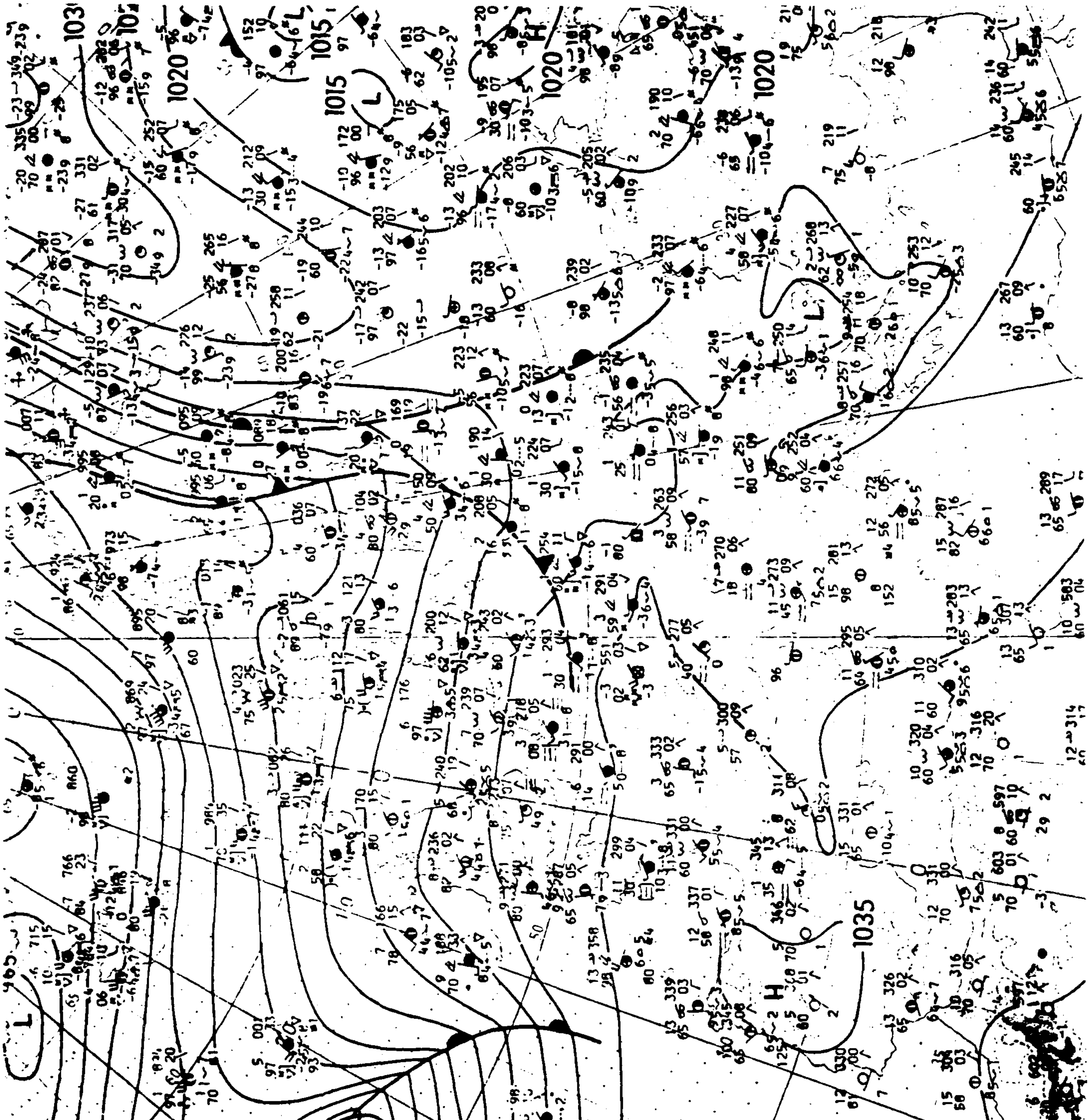

Figure 26. 2 Jan 83, 12Z - surface analysis

CASE 5. 21 January 1982. Freezing rain from cold fronts! On 21 Jan 82, at 12Z (fig 27), a cold front lies along the North Sea coasts of Denmark and Norway and crosses southwestern Germany. The cold front over Germany is weak and is sandwiched between the Azores High and the Siberian High (displaced to the southwest). A second cold front is following the first one. Both systems divide cold air east of the Rhine River Valley from mild air over France. The frontal analysis is a good example of European analysis techniques. You should infer more weather with the fronts than the fog or cold fog as shown on the map. The 850 mb analysis (fig 28) clearly shows that precipitation should fall as rain and as freezing rain since the surface is cold. The weak winds at 850 mb and 700 mb (fig 29) cannot break the inversion. Turbulent mixing warmed the lower levels but not enough to melt the thick snow cover. Dense mixing fog with below freezing temperatures caused additional icing and frost.

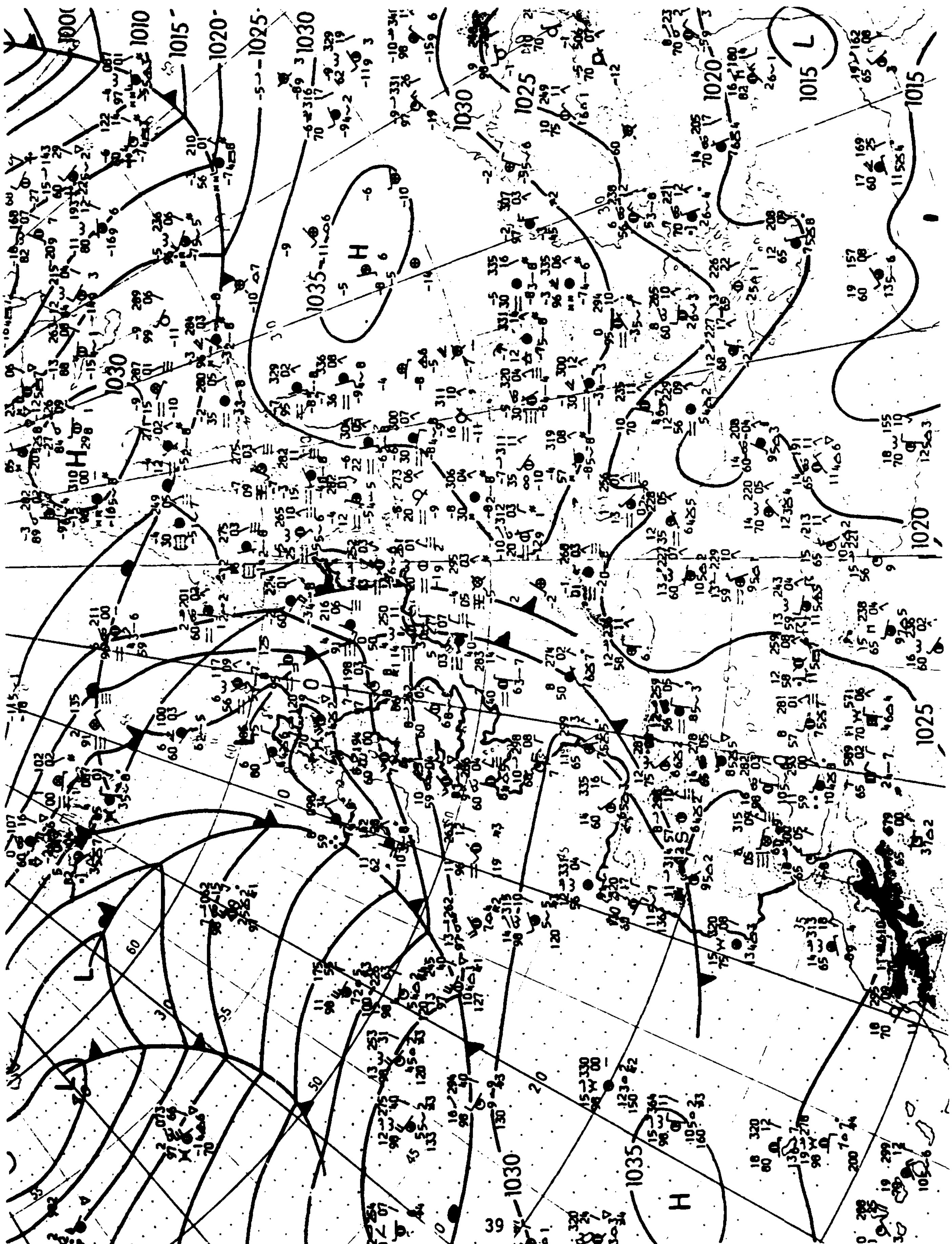

Figure 27. 21 Jan 82, 12Z - surface analysis

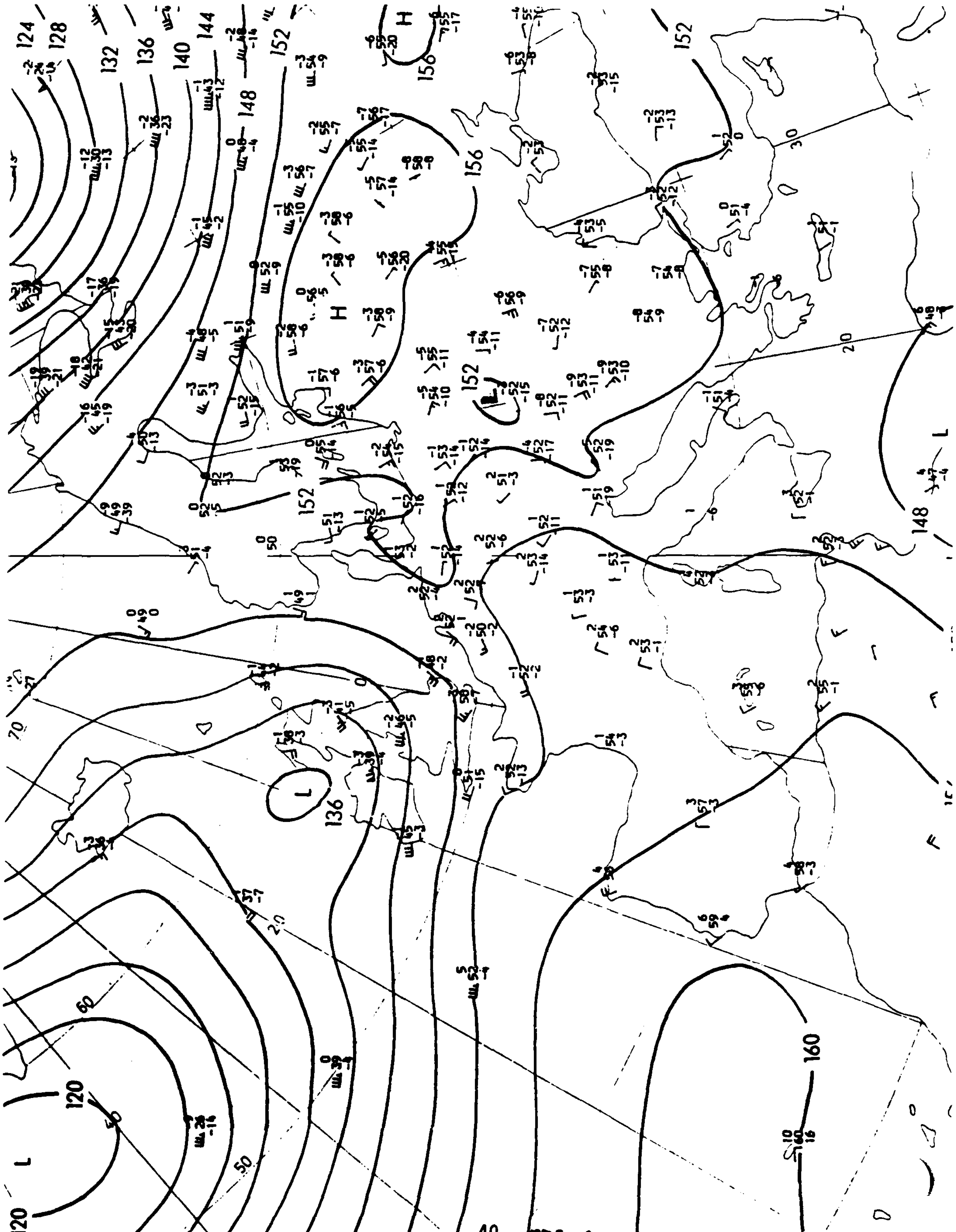

Figure 28. 21 Jan 82, 00Z - 850 mb

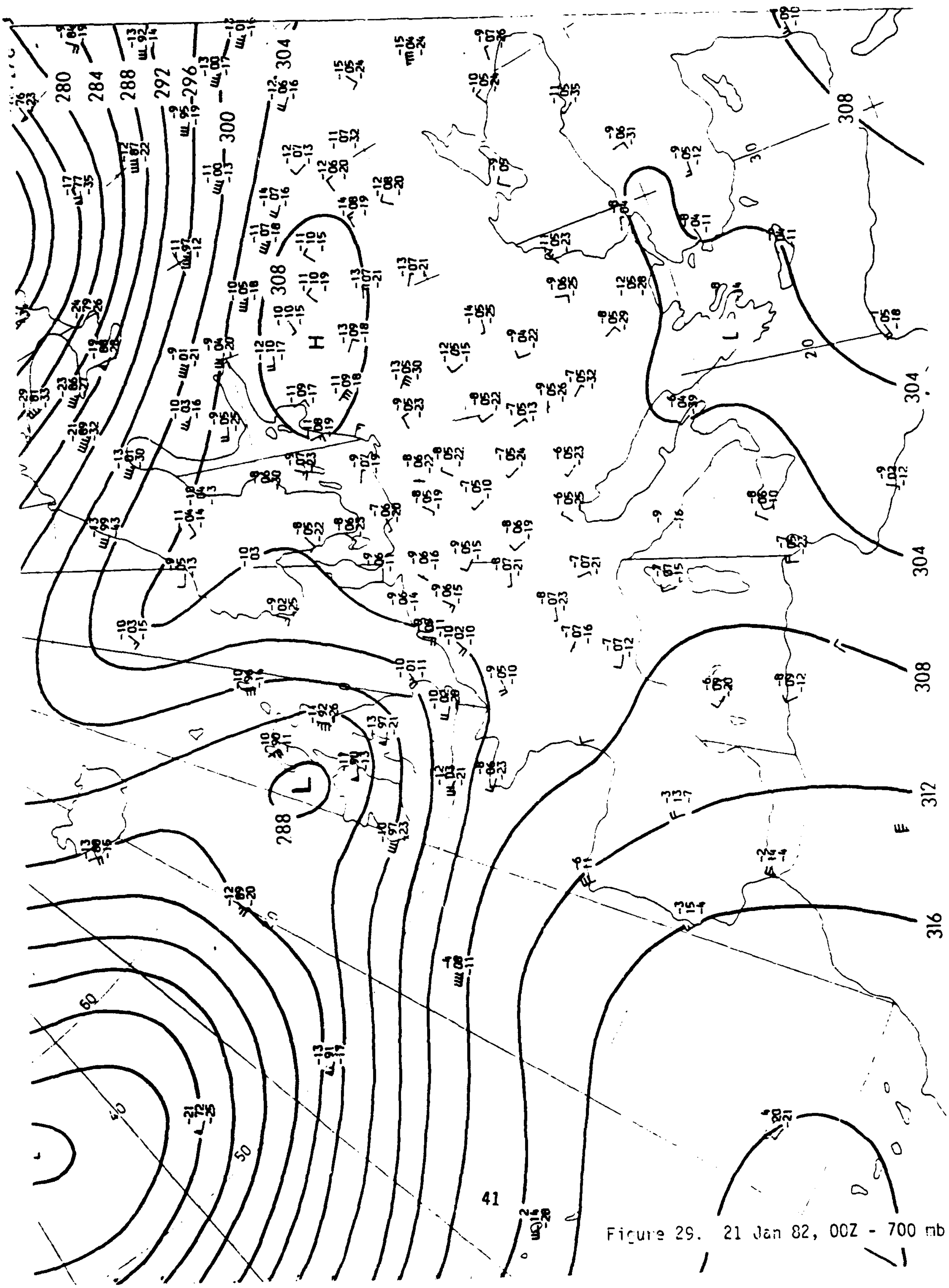

Figure 29. 21 Jan 82, 00Z - 700 mb

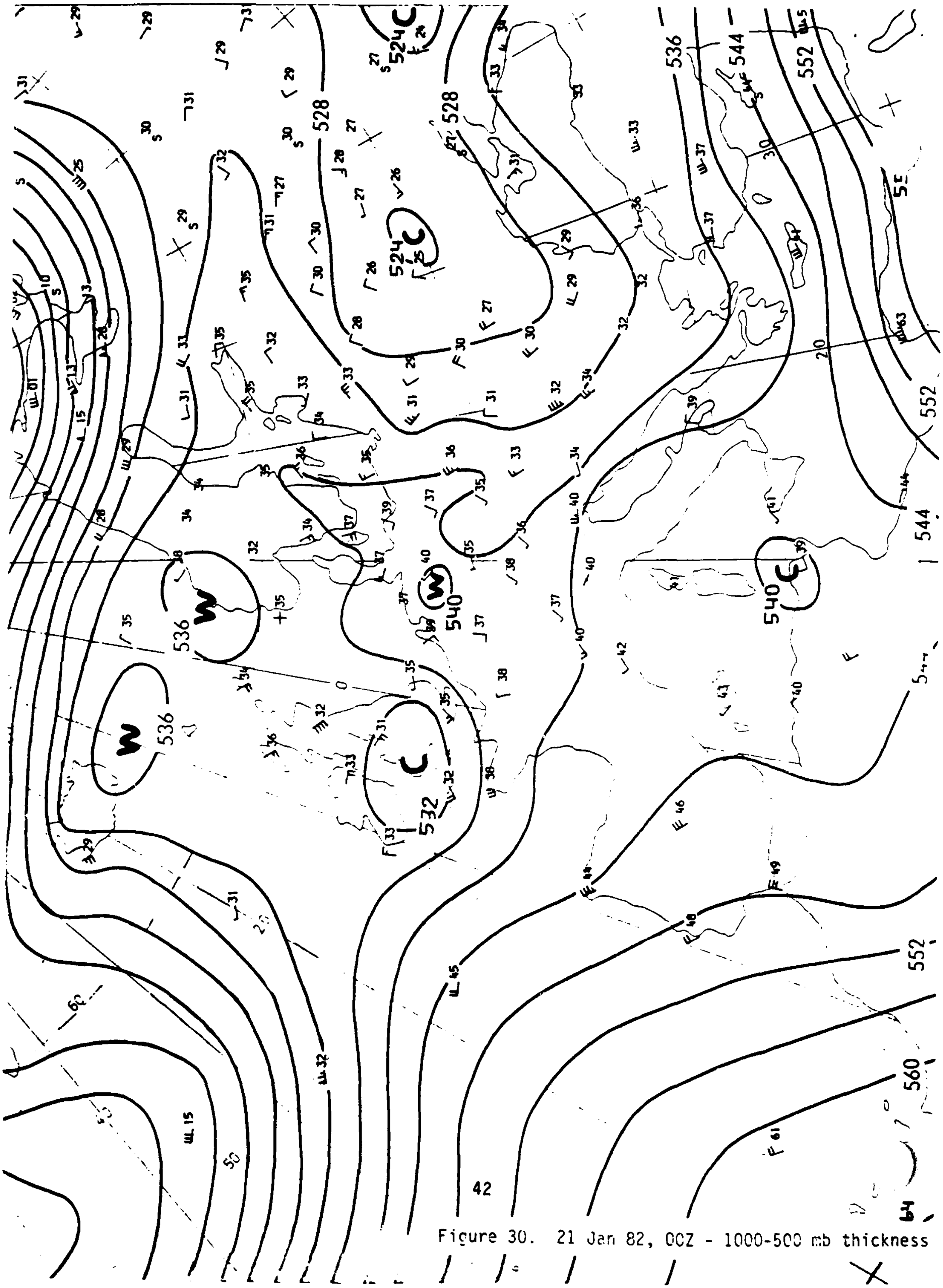

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Figure 30. 21 Jan 82, 00Z - 1000-500 mb thickness

WARM AIR ADVECTION FROM THE NORTHWEST

The title looks indeed puzzling to American forecasters that are familiar with winter weather in the northern U.S. or Canada. However, Europe is surrounded by warm water bodies to the northwest. Any air coming from the northwest has a long enough over water fetch to be modified by the sea surface temperature. However, cold upper air running behind the milder air usually has a shorter trajectory over the warm water bodies and can sufficiently lower the upper air temperature in the 850 mb and 700 mb levels. It is often a matter of timing the occlusion process. In this case, a precipitation type forecast (plus temperature forecast) can be awkward.

CASE 6. 24-25 January 1981. The surface analysis from 24 Jan 81, 12Z (fig 31) shows a low pressure system along the Norwegian coast and a cold front extending southwestward over Scandinavia, the North Sea, and into southern England where it turns back into a warm front. The Netherlands and Belgium are under the influence of the front with mixing fog and occasional drizzle. Germany, south of the Eifel mountains, is under stagnating cold air from the influence of a high pressure bridge connecting the Azores High and the Siberian High. A strong northwesterly flow aloft (figs 32 and 33) is pushing the front into Germany on the morning of 25 Jan. At 00Z, 850 mb temperatures are between -2°C and -4°C and at 700 mb, are generally warmer than -6°C. Table 2 indicates freezing precipitation, and is supported by the 1000-500 mb thickness (fig 34), which is increasing from 5370 gpm to 5400 gpm. The radiosonde ascent from Stuttgart (fig 35) shows two inversions, with temperatures above freezing at 900 mb and again at 790 mb. The winds at 850 mb are weak in the southwest (5-15 knots) and stronger only in the north and east (20-25 knots). This is not enough to completely displace the cold layer south of the Eifels so freezing precipitation is falling. Amounts are small since the front is weakening but, similar to case b(3), freezing precipitation is occurring with a cold front. This time, it came from the northwest, a feature that is virtually unknown in the U.S. However, as can be seen on the 25 Jan 81, 12Z (fig 36) the cold frontal passage considerably warmed the surface temperatures.

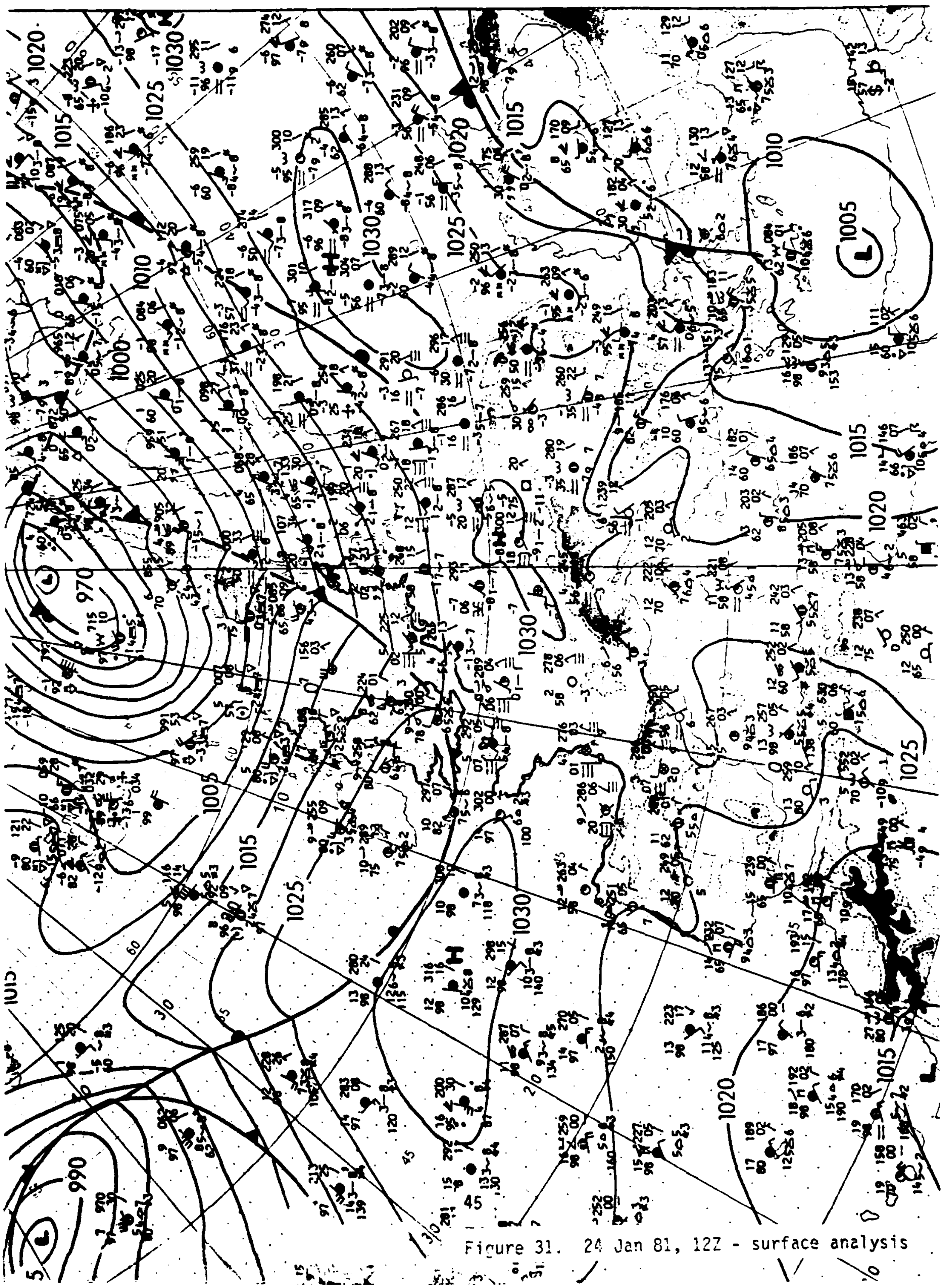

Figure 31. 24 Jan 81, 12Z - surface analysis

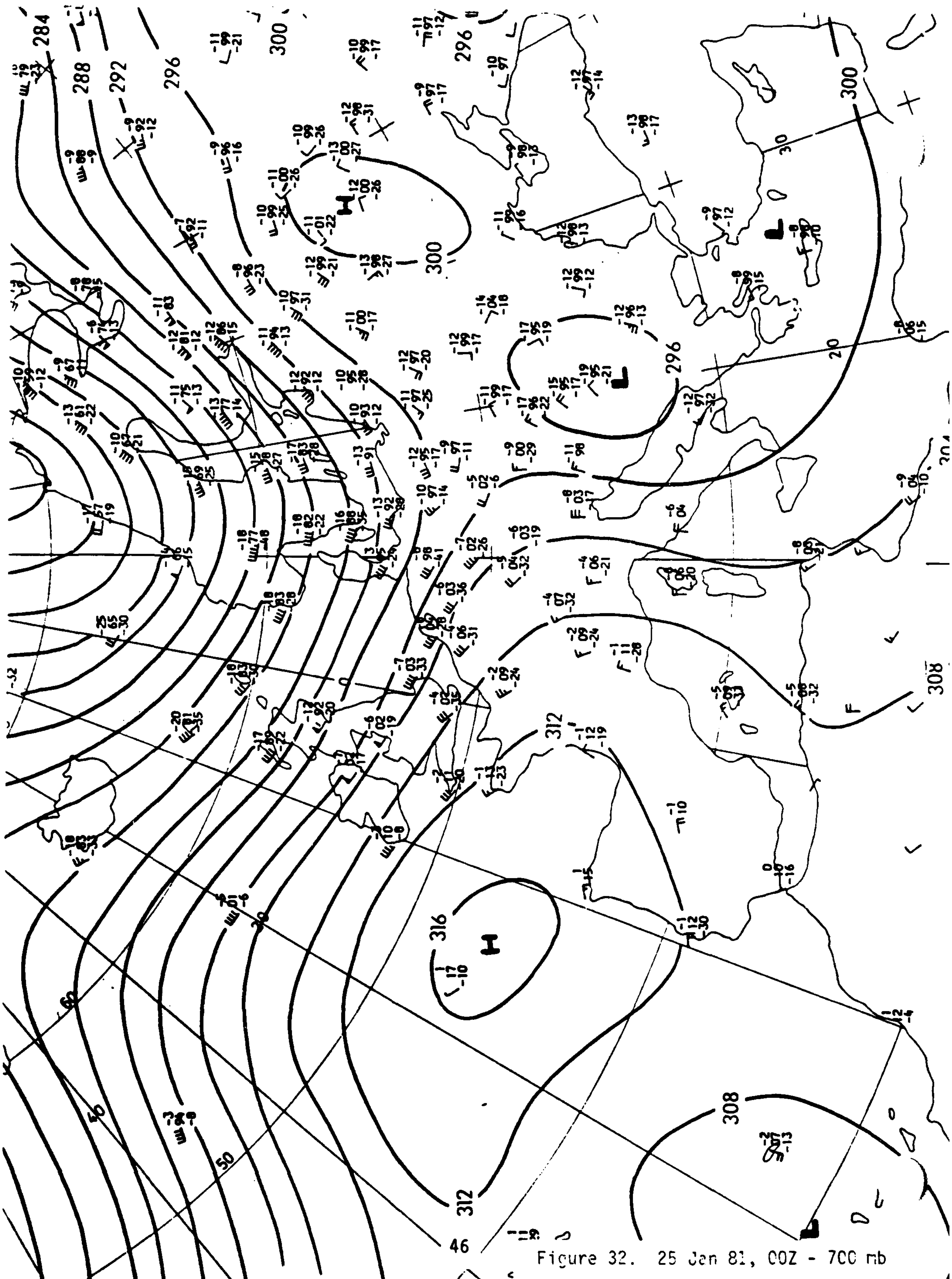

Figure 32. 25 Jan 81, 00Z - 700 mb

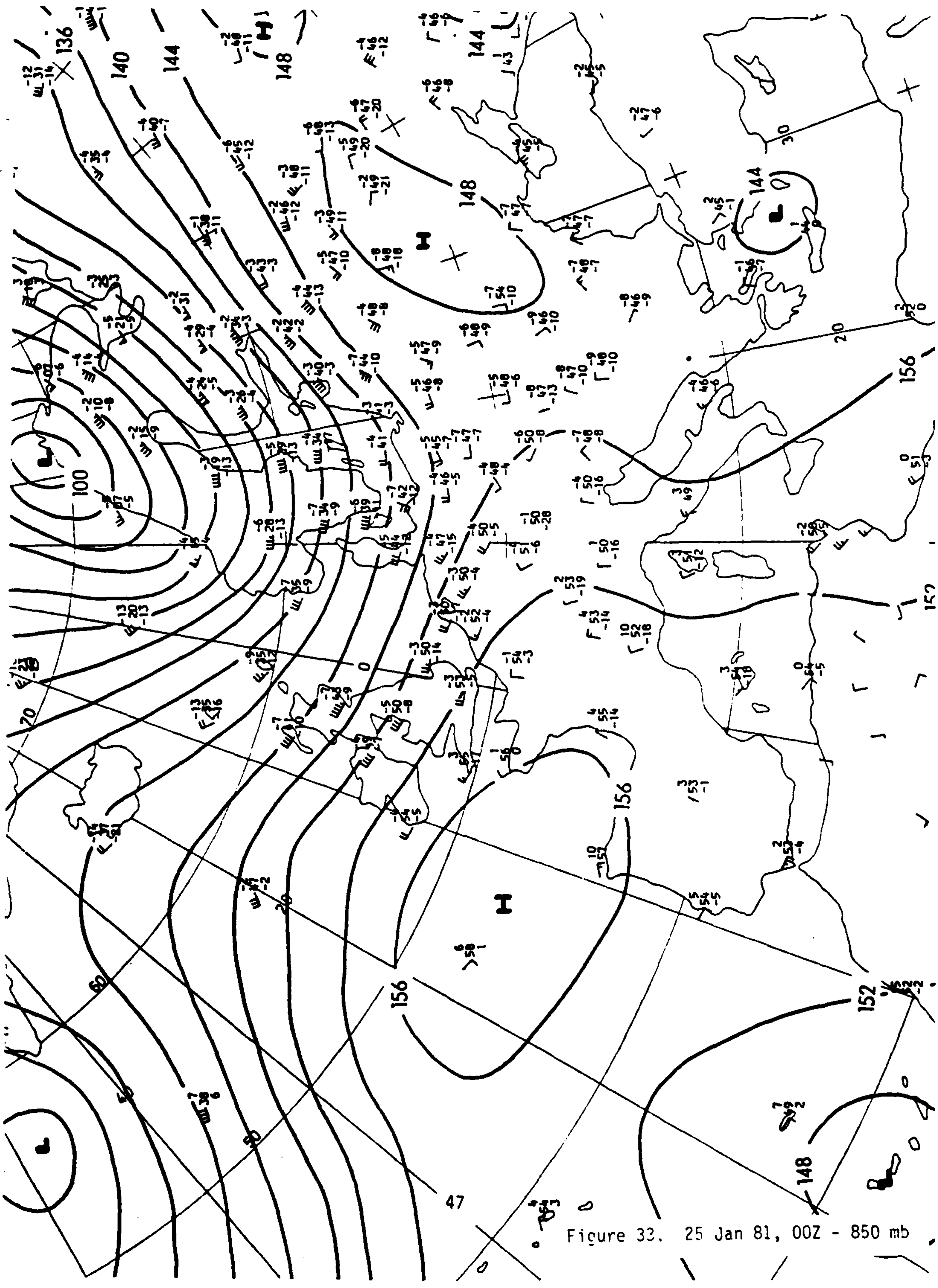

Figure 33. 25 Jan 81, 00Z - 850 mb

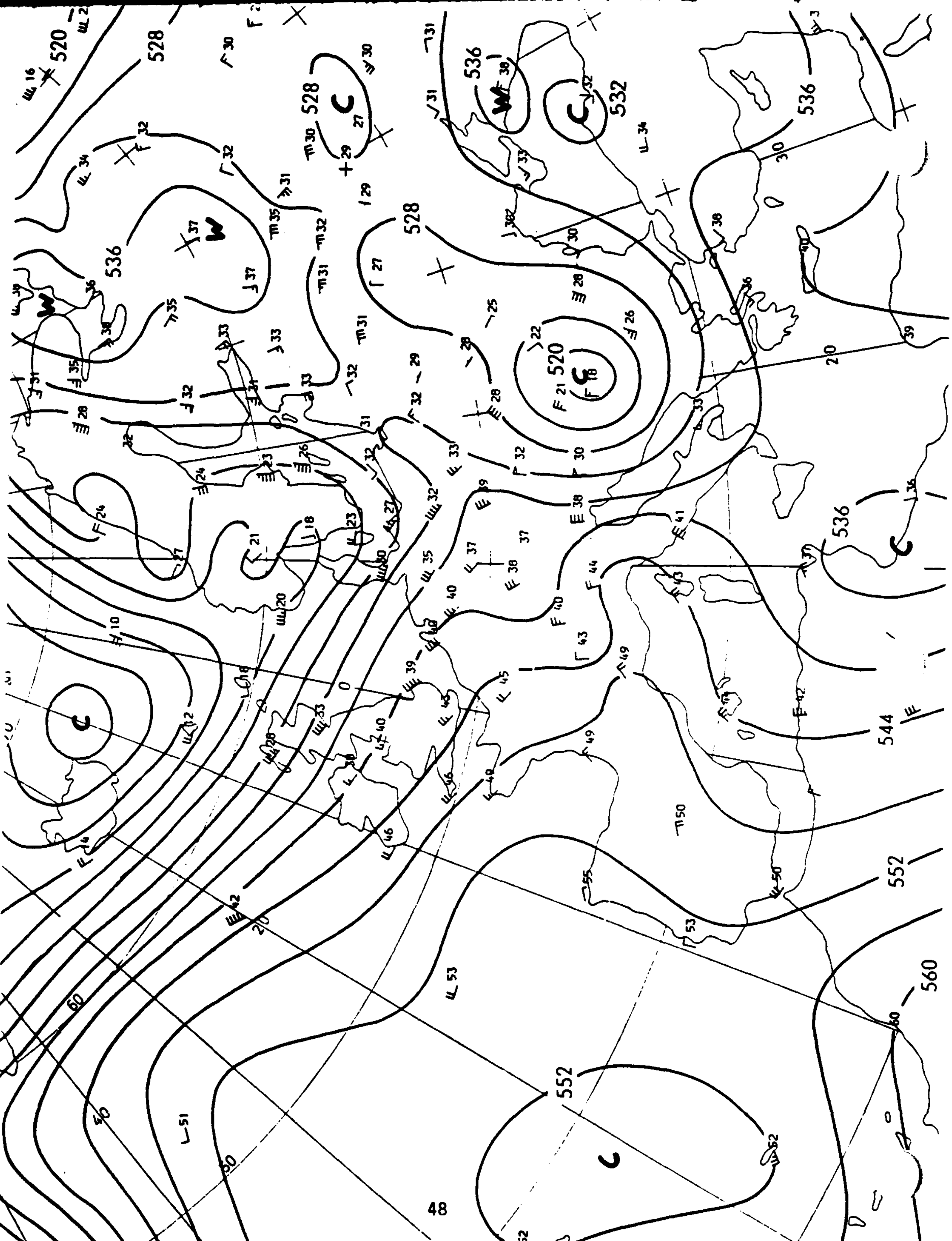

Figure 34. 25 Jan 81, 00Z - 1000-500 mb thickness

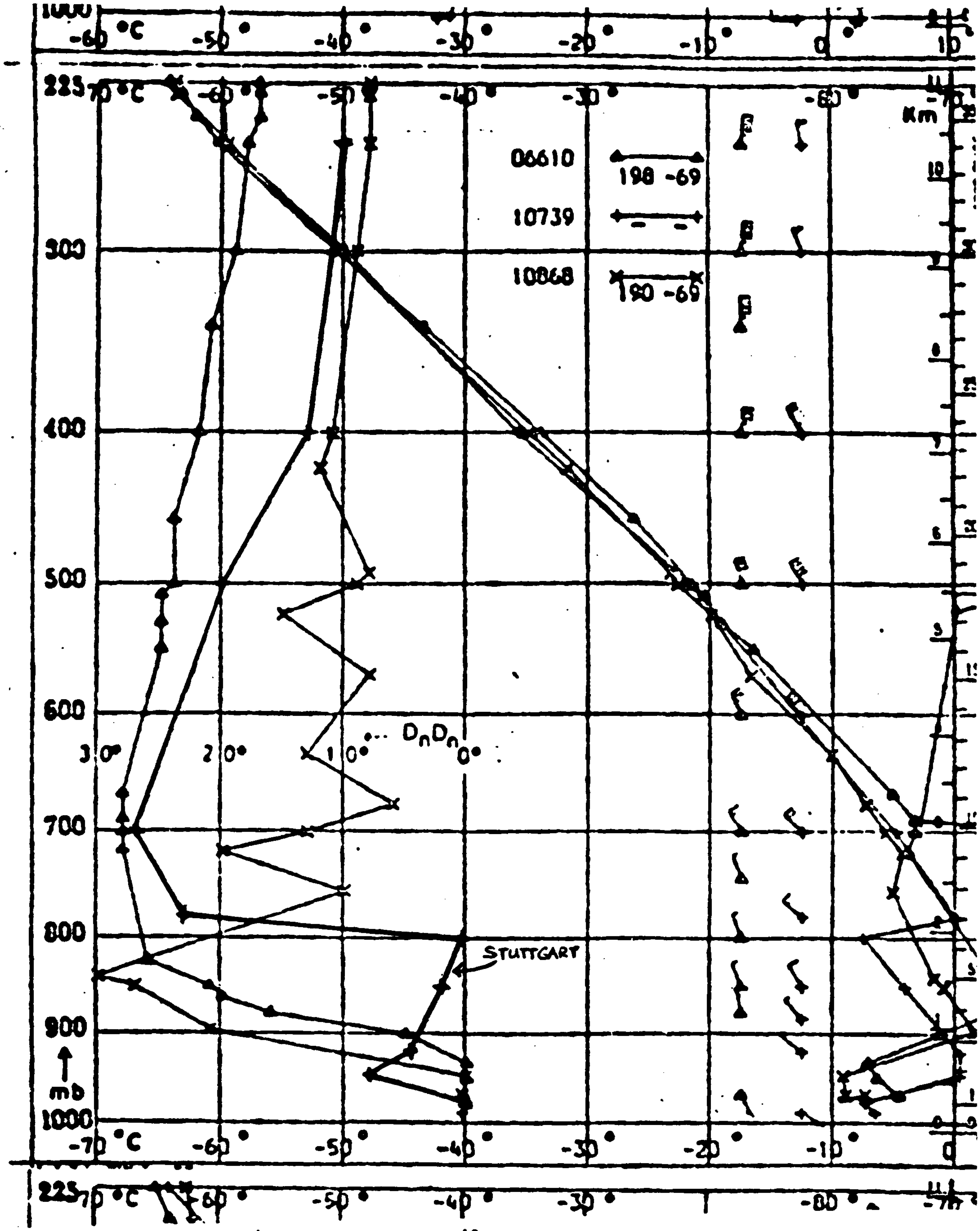

Figure 35. 25 Jan 81, 00Z-Stuttgart Radiosonde

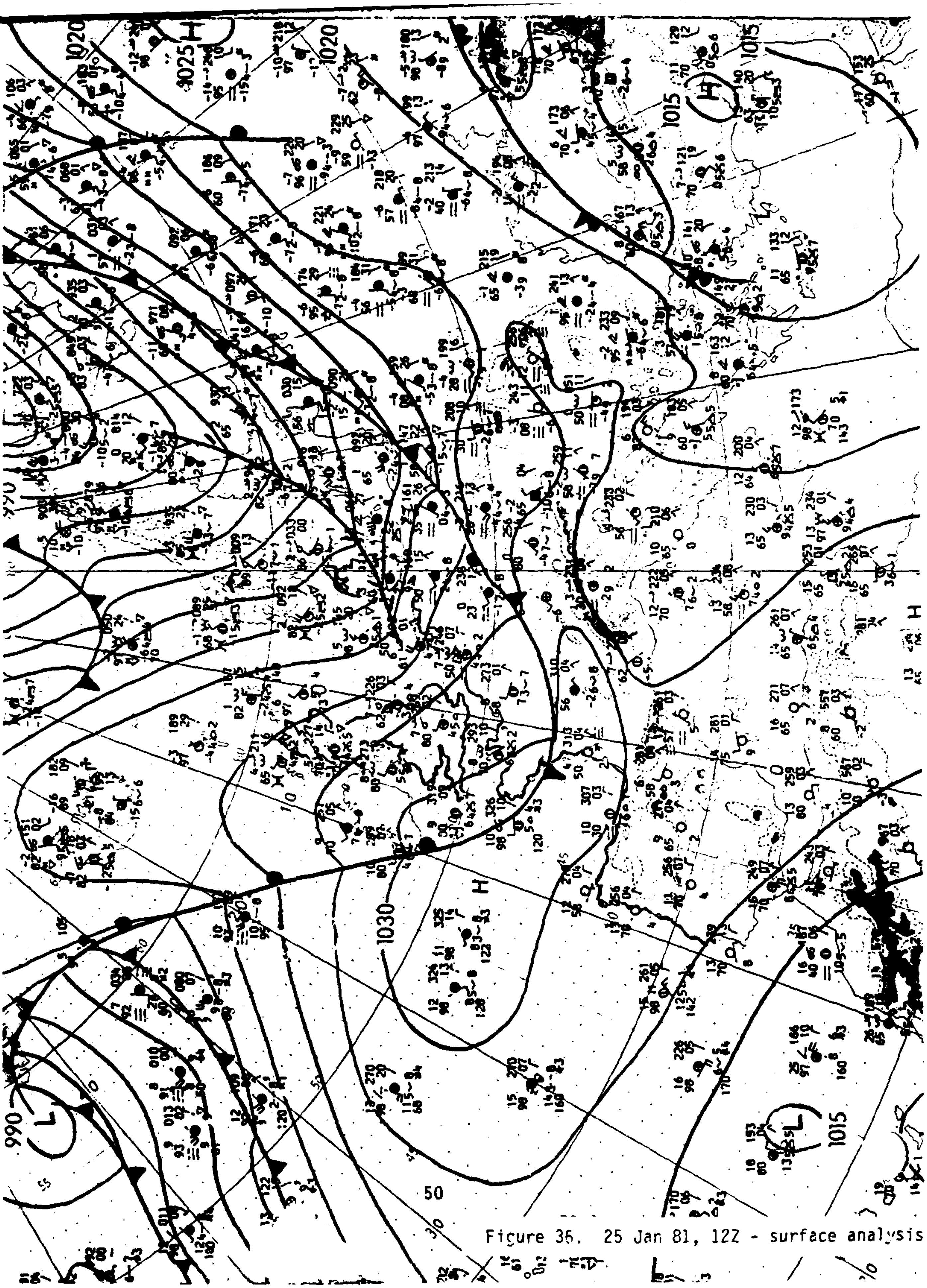

Figure 36. 25 Jan 81, 12Z - surface analysis

CASE 7. 25 January 1982. On 25 Jan 82, 12Z (fig 37), a low pressure system extends from Iceland to southern Norway. A warm front covers the North Sea, the eastern parts of the English Channel and the Bay of Biscaye. Belgium and the Netherlands have rain or drizzle, whereas over northern France, precipitation changes from snow to rain. The front is pushing southeastward into Germany against the Azores High ridge. Soundings from 00Z reveal 850 mb temperatures (fig 38) well below -5°C over Germany, but above freezing over the U.K., which is already in the warm sector. Over Germany, 700 mb temperatures (fig 39) range from -13°C to -16°C but become warmer than -7°C over the U.K. Winds at 850 mb are 10-20 knots, and are apparently (see previous cases) too weak to displace the cold air prior to precipitation beginning. Since the air is also cold aloft, precipitation should start as snow and later turn into freezing precipitation. The downslope effect of the Eifel, the Sauerland, and the Harz Mountains is strong enough to displace the cold air at the surface in southern Germany. There are regional and local variations due to terrain (downslope-upslope-downslope) but generally, the precipitation began as snow, became freezing precipitation and turned into rain (with mixing fog). Along the Alps, the strong upslope trapped the cold air resulting in large amounts of snow. As the air warmed, the precipitation turned into rain. Over this area the freezing precipitation stage was missing.

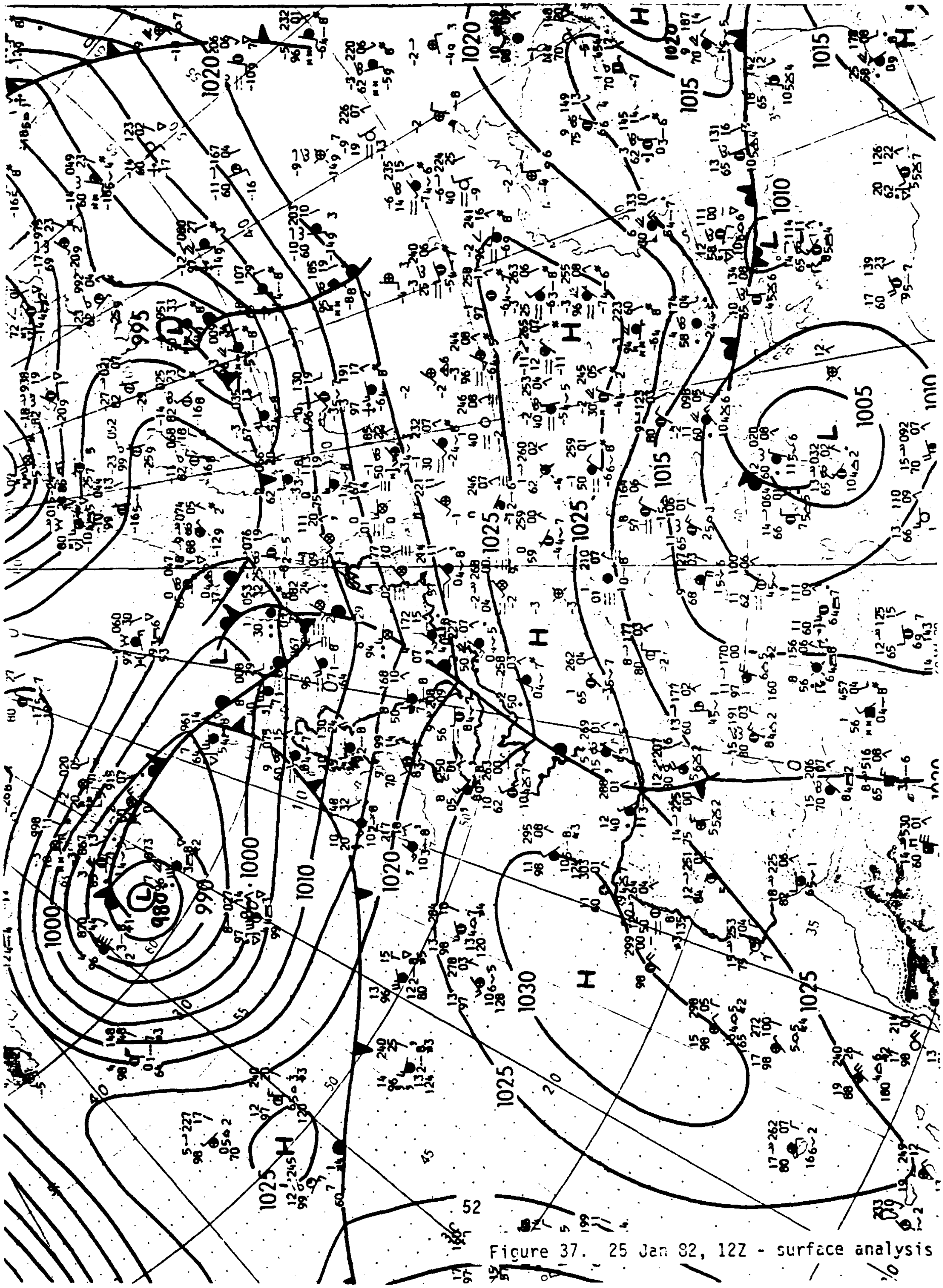

Figure 37. 25 Jan 82, 12Z - surface analysis

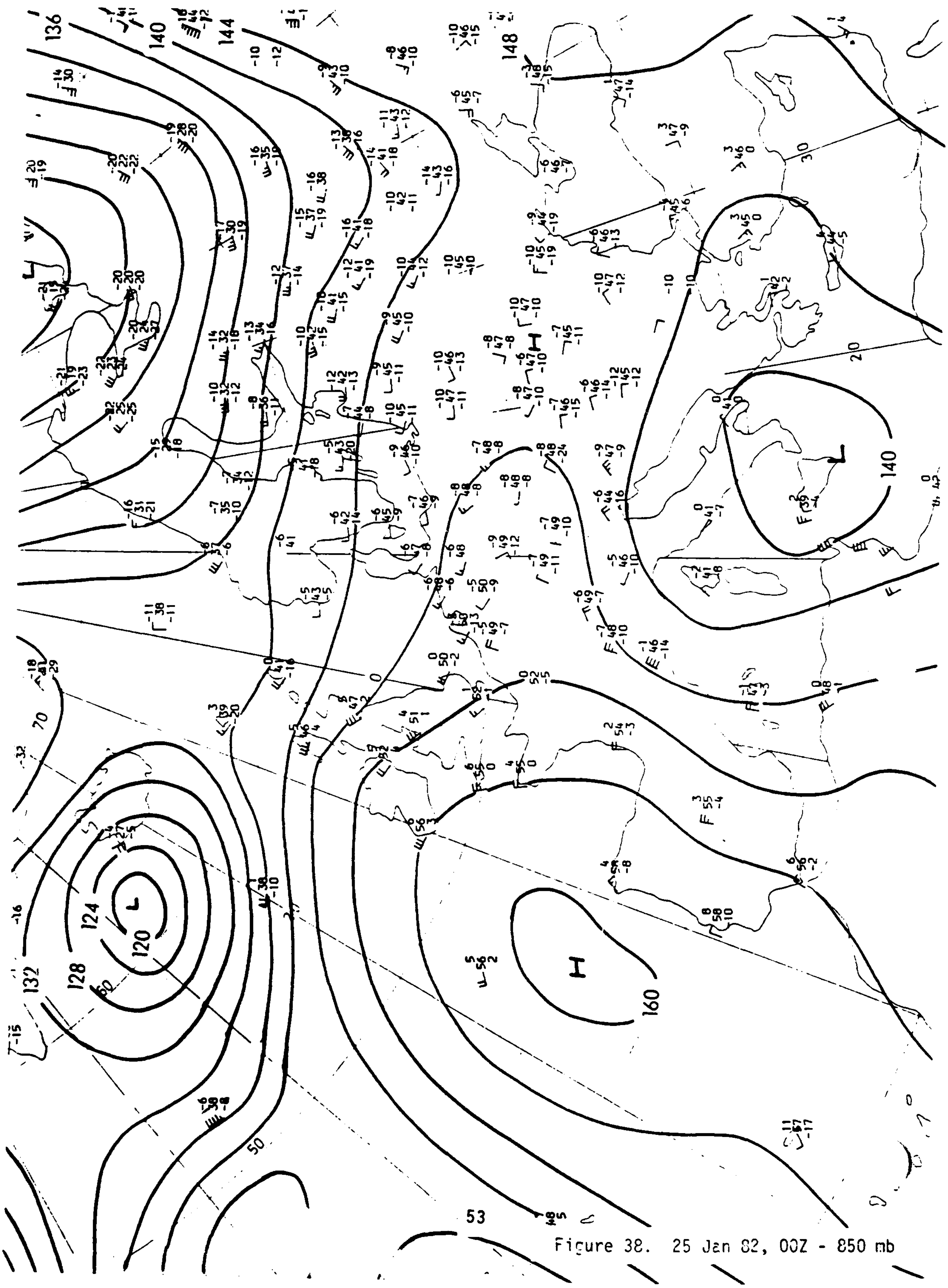

Figure 38. 25 Jan 82, 00Z - 850 mb

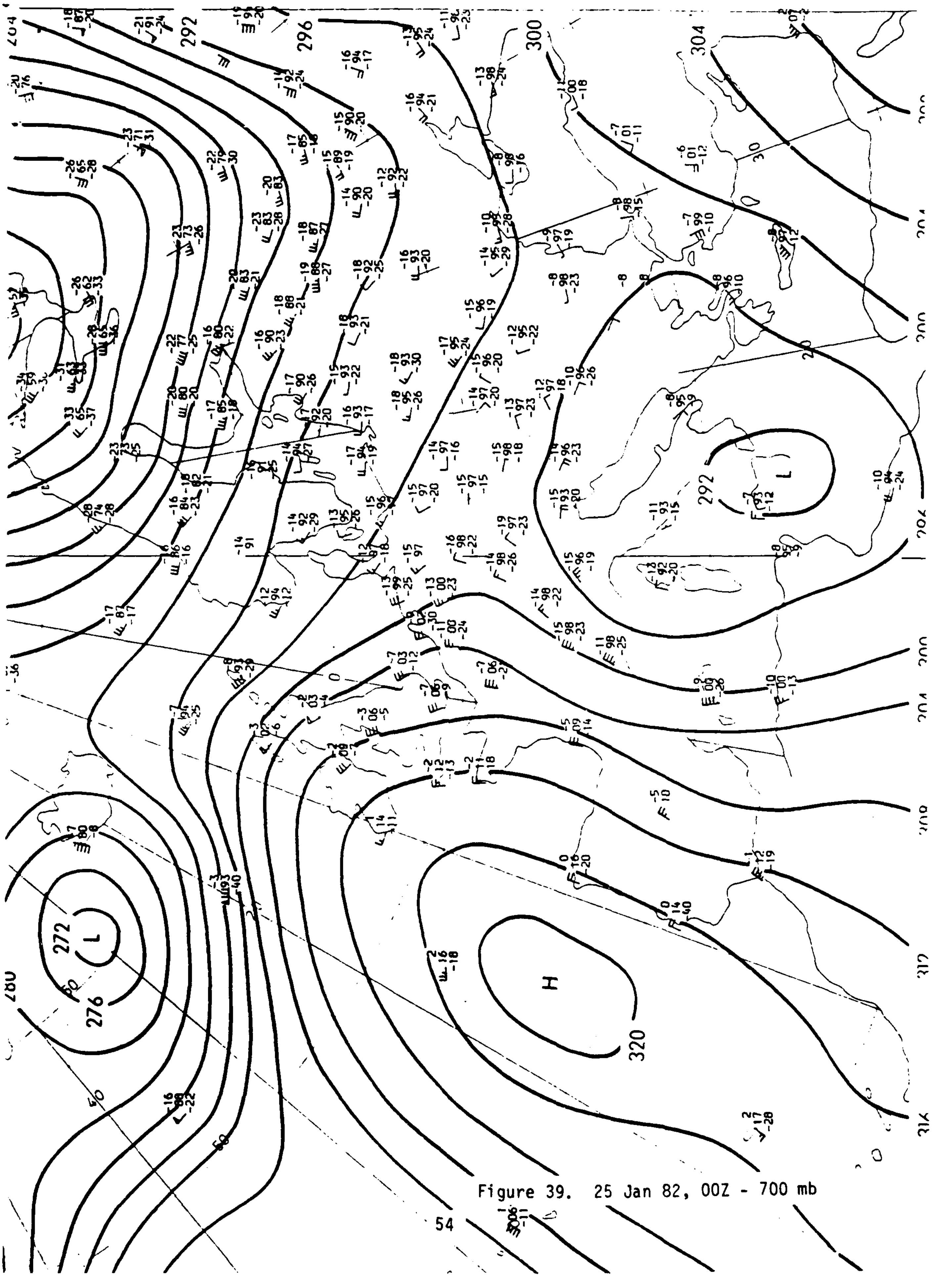

Figure 39. 25 Jan 82, 00Z - 700 mb

CASE 8. 8-10 January 1981. Freezing precipitation turned into snow. At 12Z, 8 Jan 81 (fig 40), central Europe is under high pressure with a deep low centered south of Svalbard and a warm front extending from Norway over the North Sea into France. The cold front extends southeastward over the Norwegian Sea and the northern Atlantic Ocean. A broad warm sector covers the British Isles. The warm front is slowly moving southeastward. Belgium and the Netherlands are already above freezing, while temperatures in Germany and Denmark are below freezing. By 9 Jan, 00Z (fig 41), the warm front has reached the Eifels, and 850 mb temperatures (fig 42) are above freezing. South of the Main River, the 850 temperatures are colder than -8°C. At 700 mb (fig 43), temperatures are less than -10°C in southern Germany, and -8°C to -10°C over northwestern Europe. Within the warm sector 1000-500 mb thickness values (fig 44) are increasing from 5330 gpm to over 5400 gpm. This suggests a forecast of rain, and since 850 mb winds are less than 20 kts, a continuation of the cold temperatures south of the Eifels. The surface map for 9 Jan 12Z agrees, but Rhein-Main has light snow with a weak southwesterly wind. This is due to the mixing of the cold air at 850 mb with the warmer air, since freezing precipitation was observed later. Freezing precipitation occurred in southwest Germany during the day. The weakening warm front is not able to displace the cold air at the surface. During the night of 9/10 Jan, surface temperature remained below freezing and intermittent freezing precipitation was observed. On 10 Jan, 00Z (fig 45), the cold front is crossing Belgium and northwest Germany. At 850 mb (fig 46), temperatures are between -1°C and -2°C and are cooling as a trough immediately following the cold front moves through. Things are more clear at 700 mb (fig 47), where temperatures drop from -11°C over Germany and the Netherlands to -18°C over southeastern England. In accordance, thickness values (fig 48) are decreasing with values around 5340 and 5330 gpm over Germany. As the cold front passes over the Eifels and the warm air mixes with the cold air, the front becomes a warm-frontal occlusion and the shallow warm air layer between 900 mb and 850 mb is cooled. Consequently, the precipitation associated with the cold front/warm front occlusion changed from freezing precipitation into snow and dropped several inches of snow in Germany south of the Eifels, including Rhein-Main. The surface analysis on 10 Jan 81, 12Z (fig 49) shows the position of the front extending from Fulda to Rhein-Main to Ramstein. The warm tongue which was apparent on previous analyses is virtually absorbed by the cold air. This case suggests using the following freezing precipitation thresholds:

(a) 850 mb temperature $\geq$ - 2°C
(b) 1000-500 mb thickness $\geq$ 5330 gpm (dependent on elevation)
(c) 700 mb temperature $\geq$ - 9°C

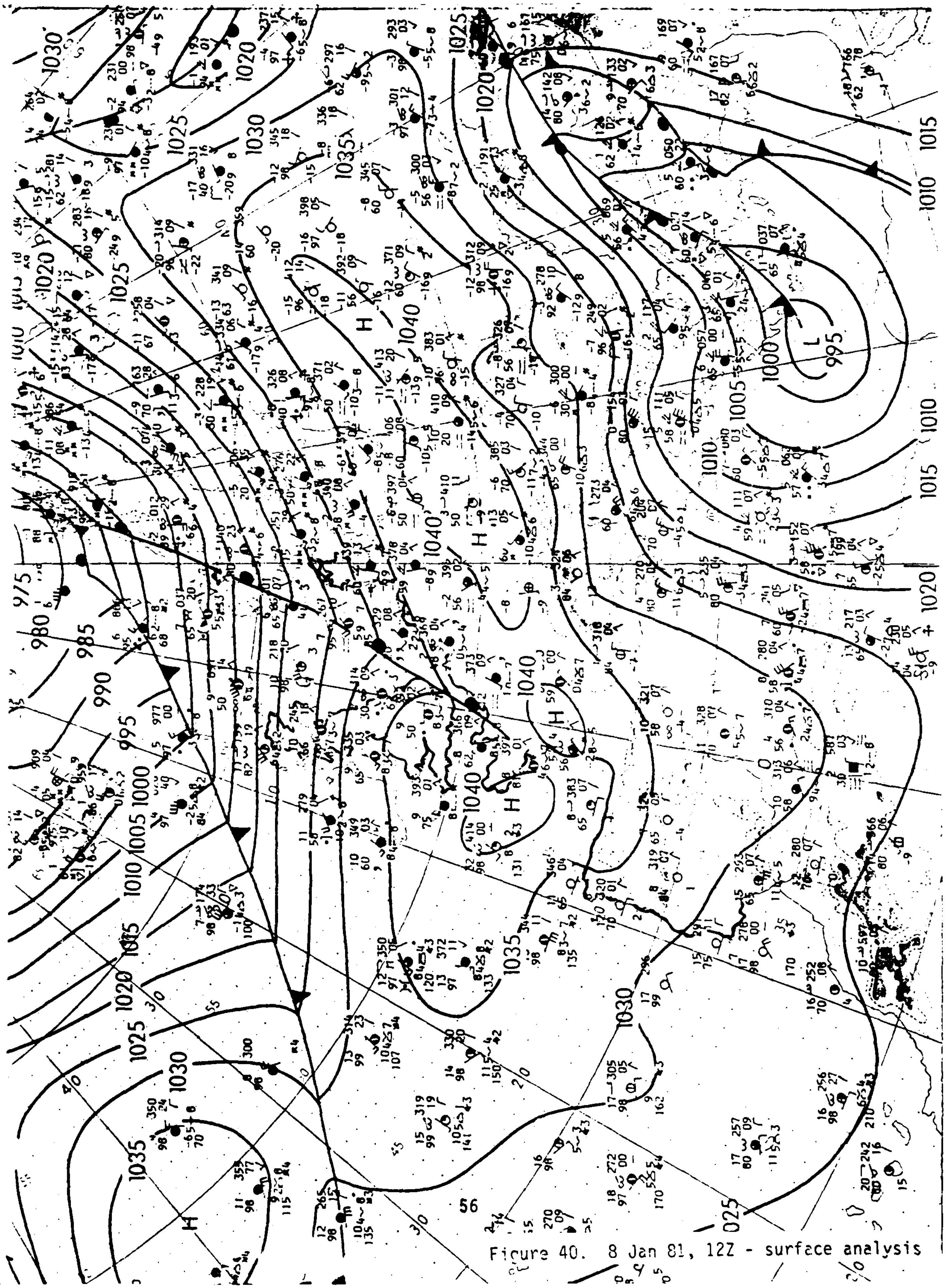

Figure 40. 8 Jan 81, 12Z - surface analysis

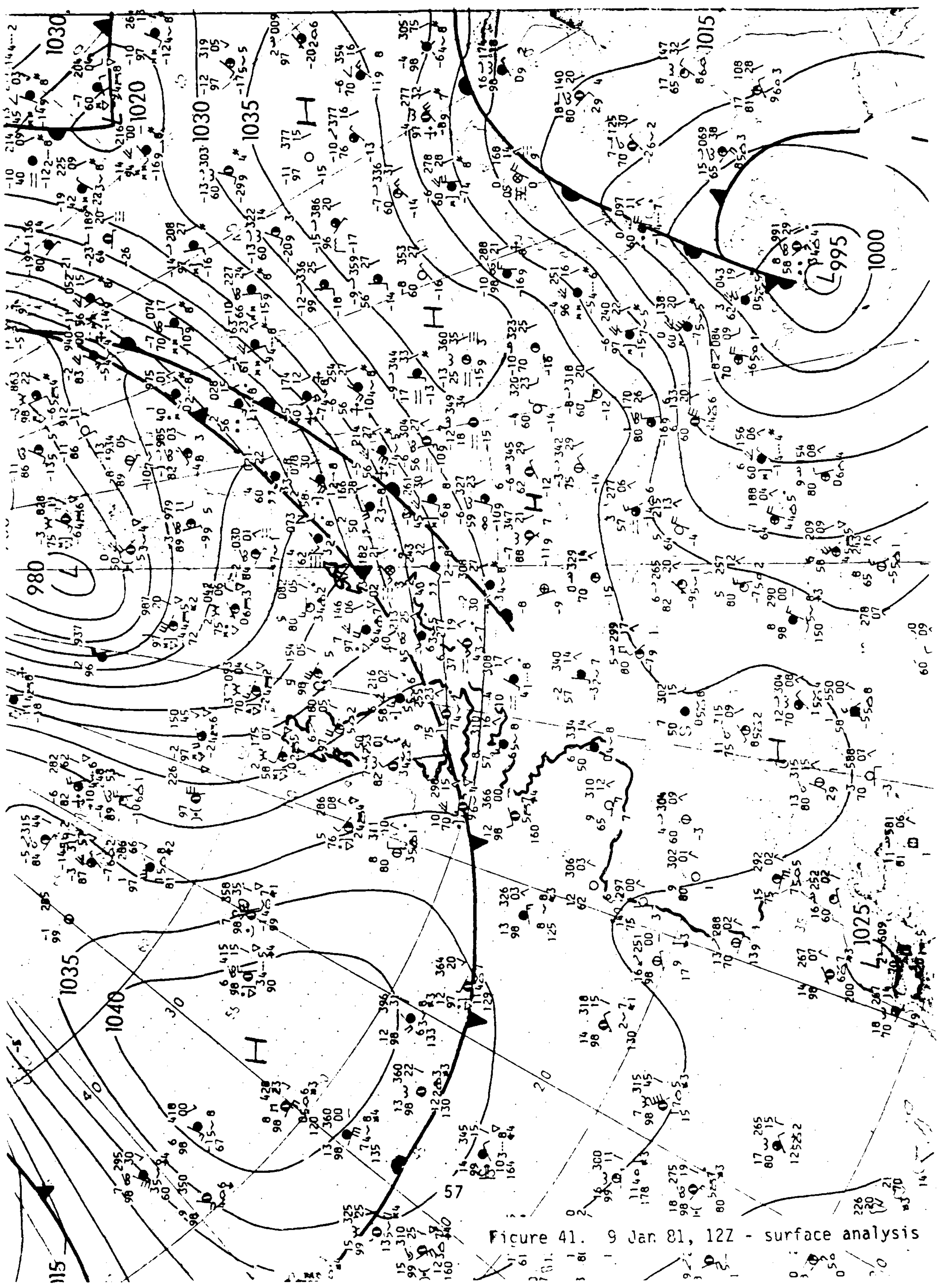

Figure 41. 9 Jan 81, 12Z - surface analysis

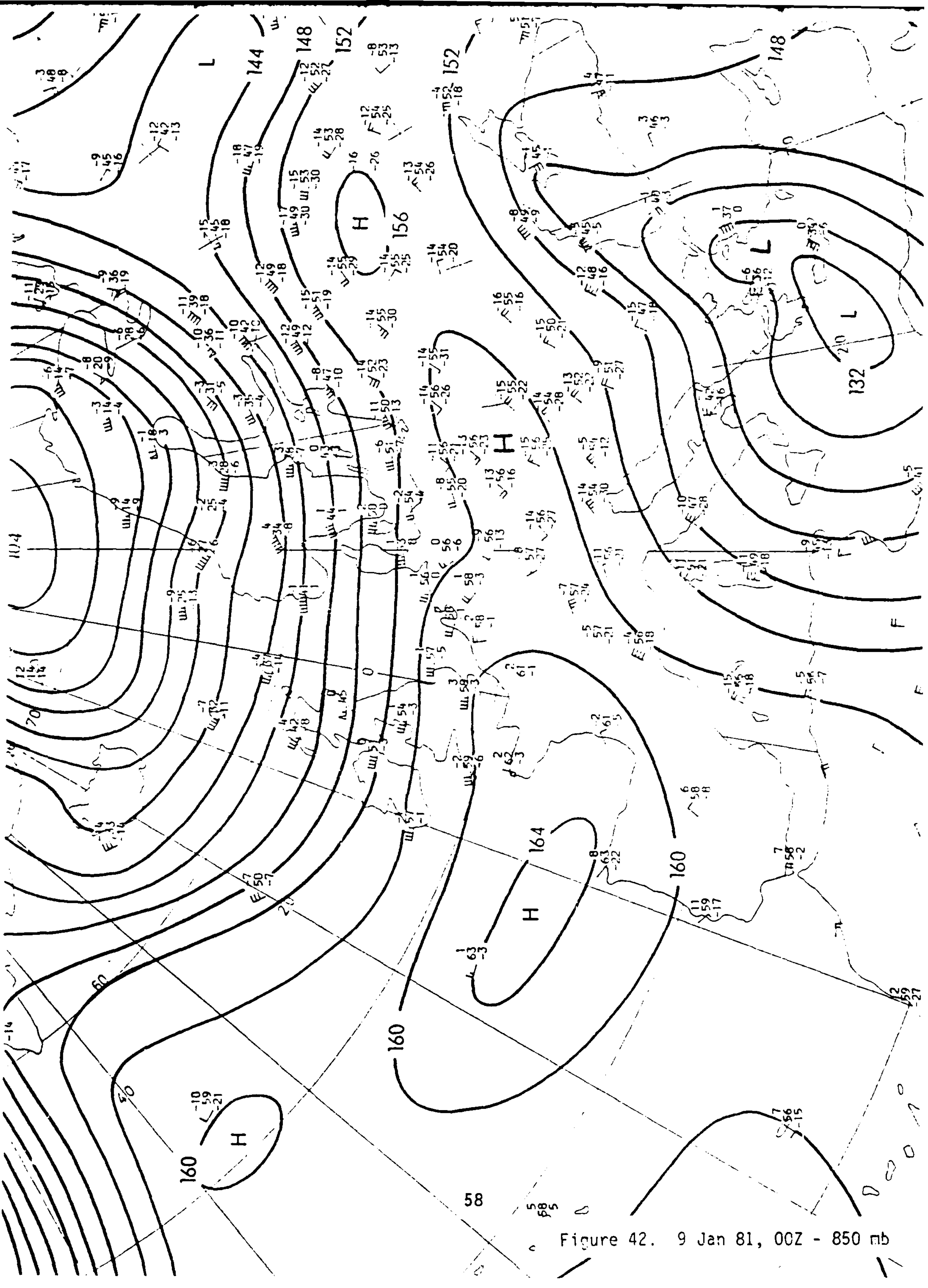

Figure 42. 9 Jan 81, 00Z - 850 mb

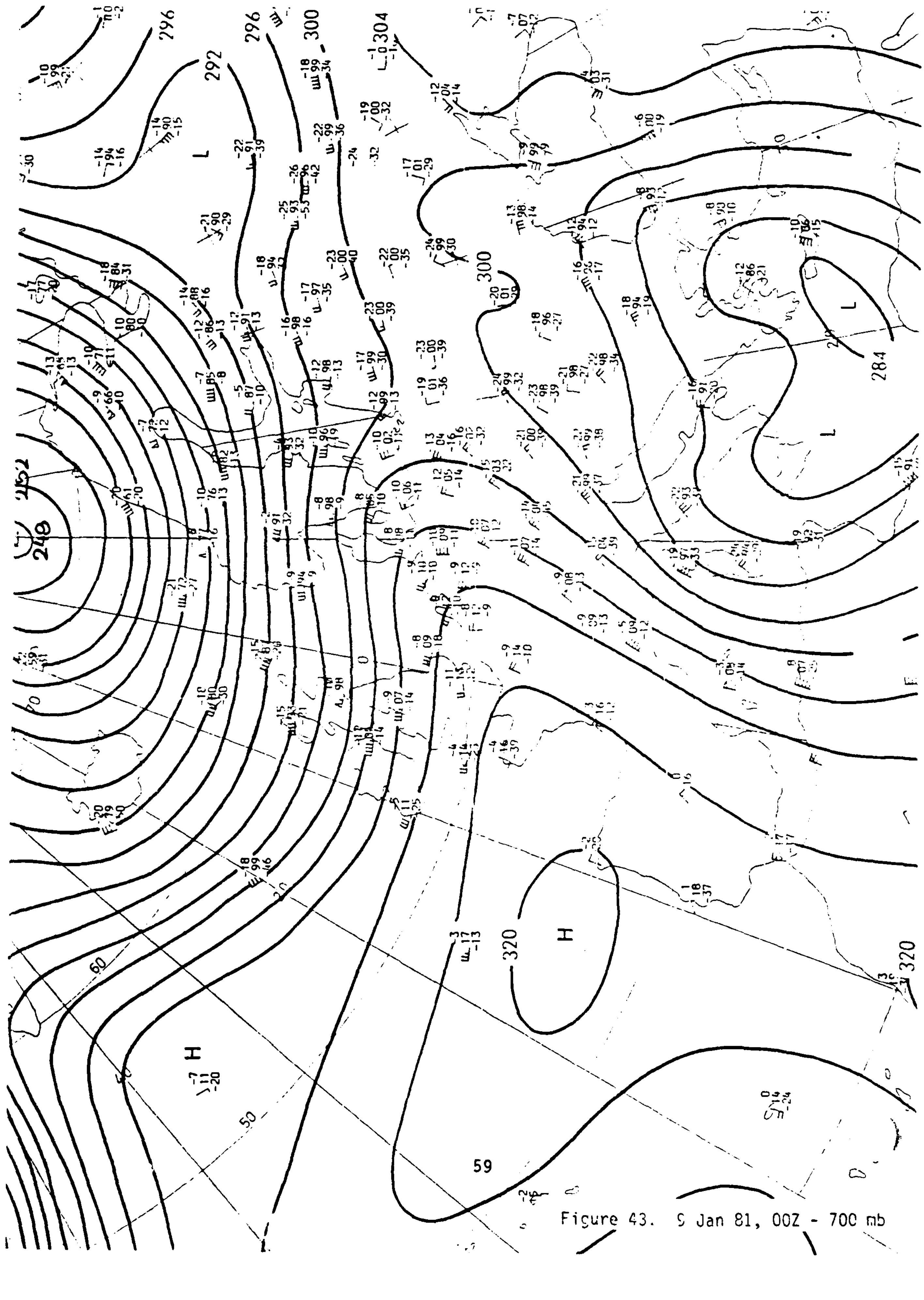

Figure 43. 9 Jan 81, 00Z - 700 mb

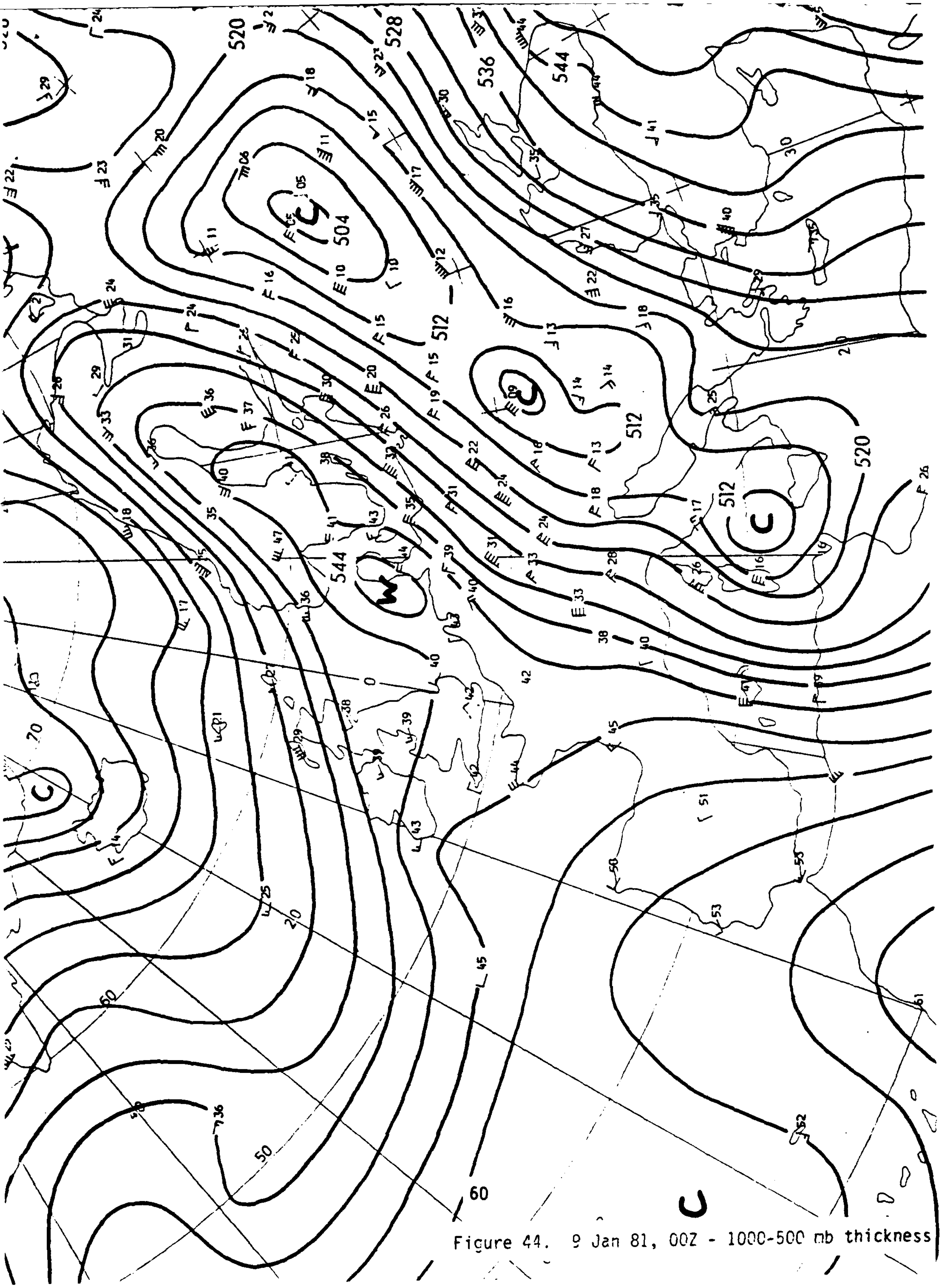

Figure 44. 9 Jan 81, 00Z - 1000-500 mb thickness

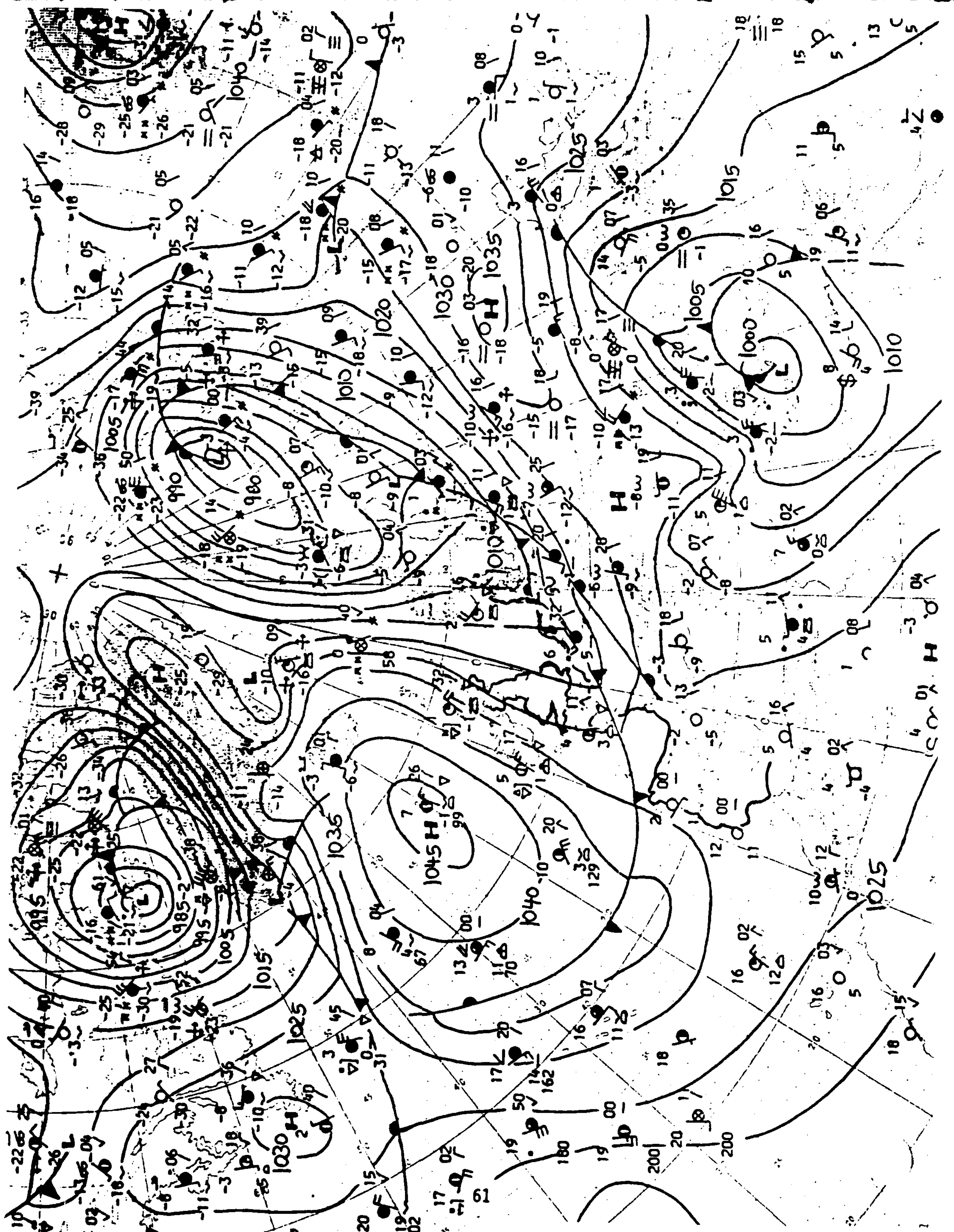

Figure 45. 10 Jan 81, 00Z - surface analysis

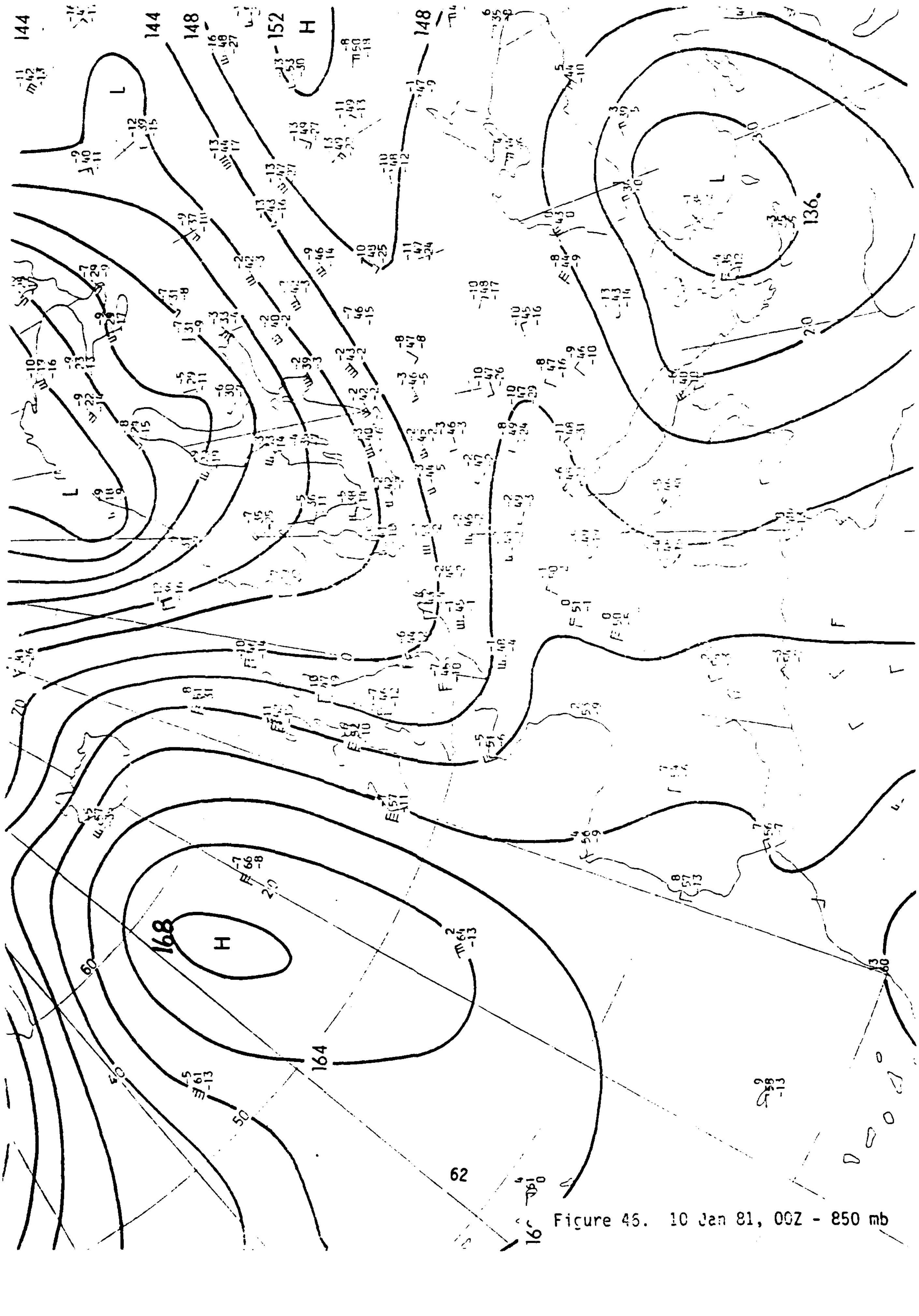

Figure 46. 10 Jan 81, 00Z - 850 mb

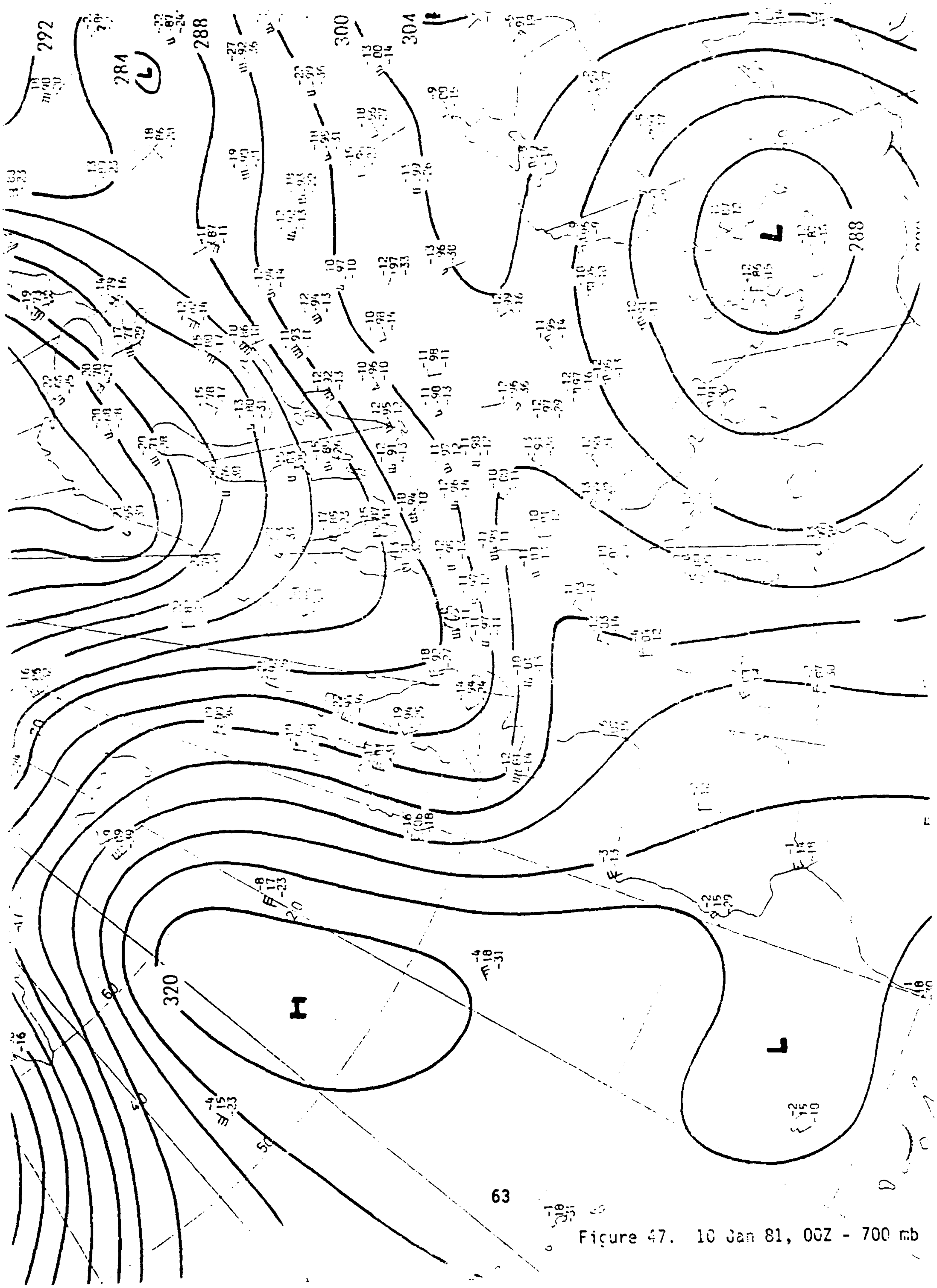

Figure 47. 10 Jan 81, 00Z - 700 mb

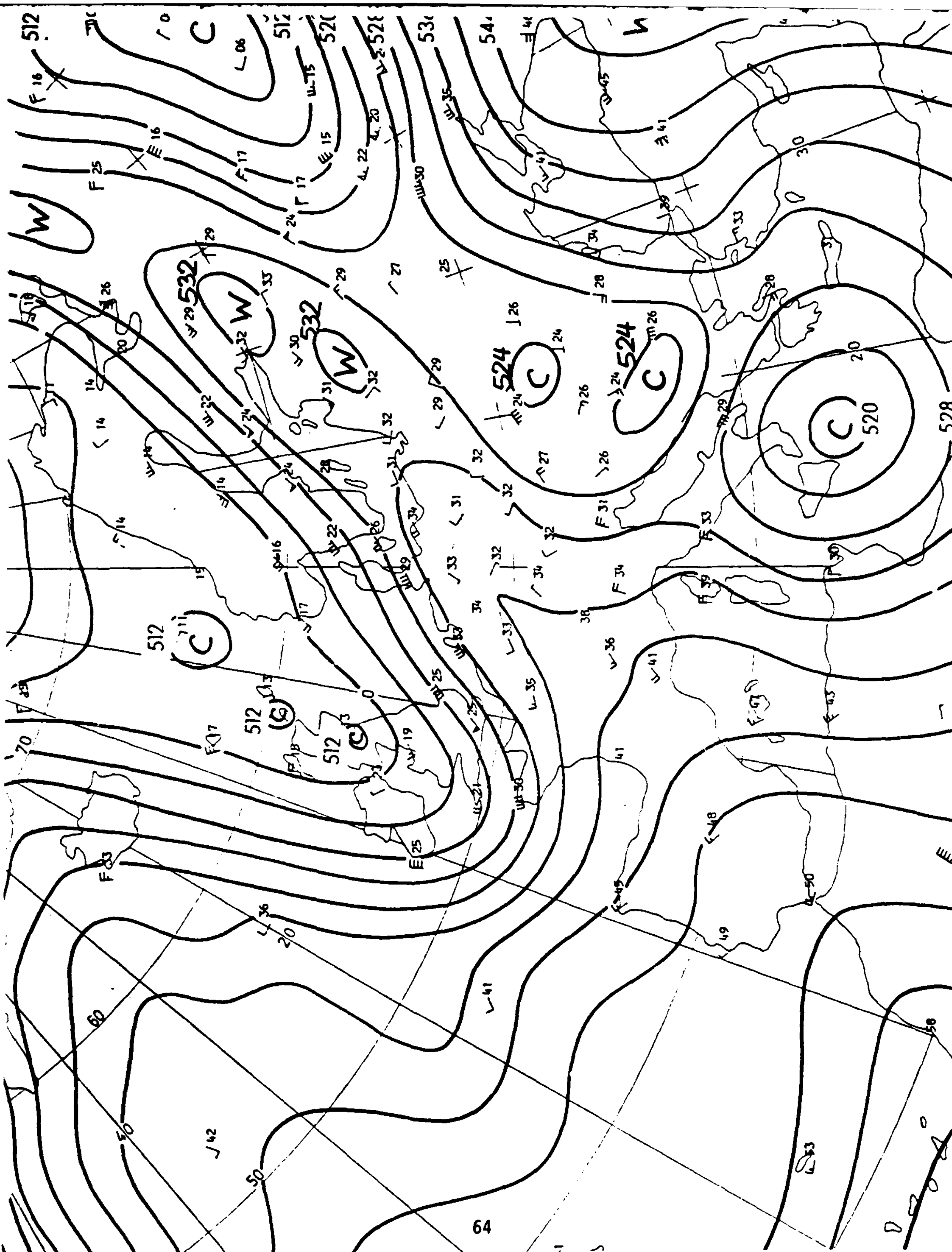

Figure 48. 10 Jan 81, 00Z - 1000-500 mb thickne

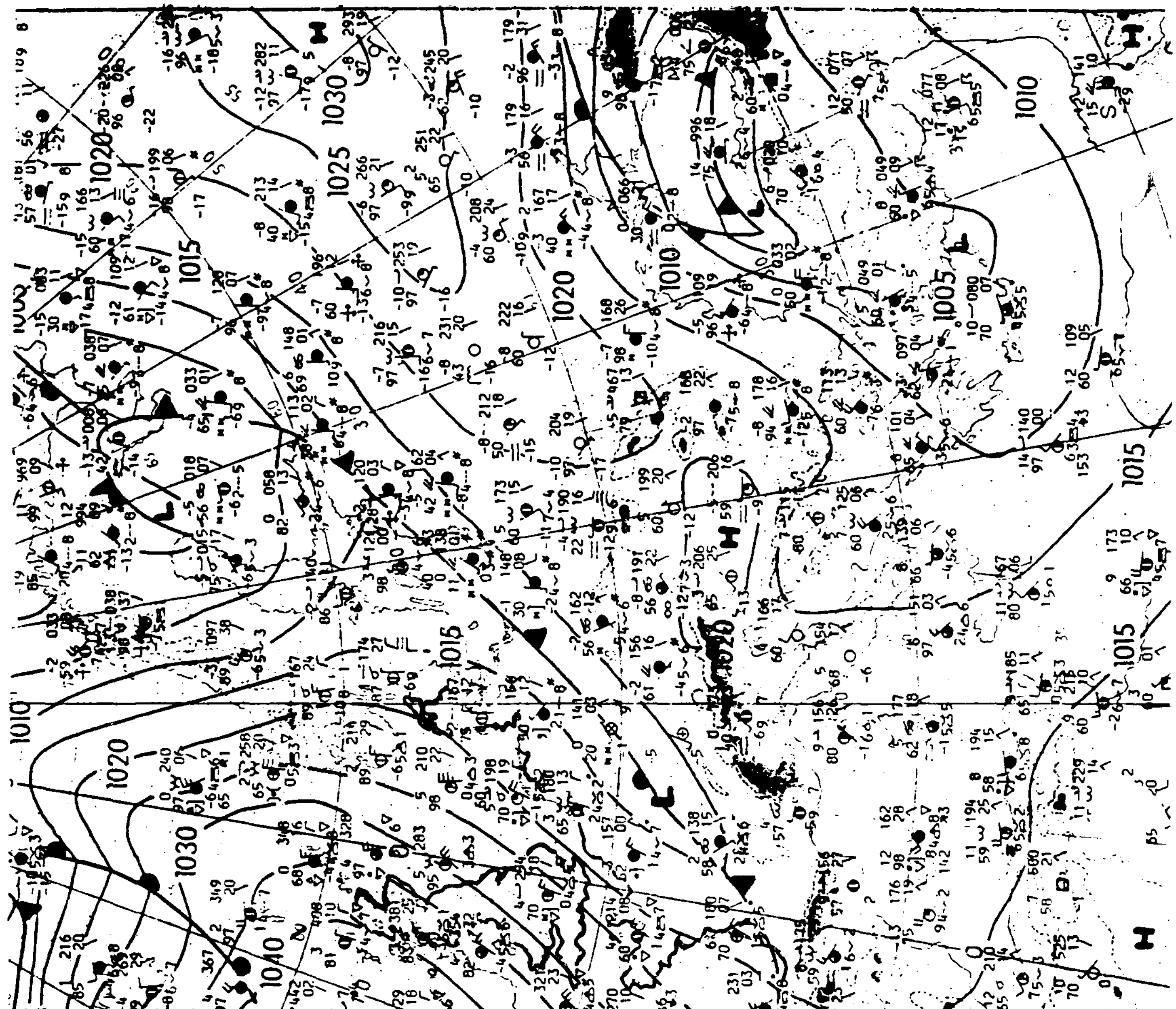

Figure 49. 10 Jan 81, 12Z - surface analysis

UNUSUAL CASES

This section basically includes cases which you may not even have thought about because of its apparent (at first glance) strange behaviour. These situations are anything but rare, although they usually do not produce freezing rain. Take your time and thoroughly check these cases. There is material in them that will help you. These cases basically tell you that freezing rain can be expected with a flow from any direction. Remember, even though central Europe shares the same latitude with southern Canada, there are water bodies around that hardly ever freeze in winter.

CASE 9. 17-18 December 1980. The surface analysis on 17 Dec 80, 12Z (fig 50) shows a deep low over the Norwegian Sea and a warm front extending southwestward from Norway over the North Sea into western France, immediately followed by a cold front. The synopsis has some similarities to case 6. Again, central Germany is under ridging from the Azores High and surface temperatures are near or below freezing. Northern Germany, the Netherlands, and Belgium already have warmer temperatures. This case looks like rain at first glance since temperatures in England are above 10°C. The 850 mb temperatures from 18 Dec 00Z (fig 51) support this idea as temperatures warm from -4°C to +2°C with frontal passages. However, a broad trough over the Benelux with colder air behind is cause for concern, especially after looking at the 700 mb level (fig 52). Another problem is the wind. The 40-55 kt winds should warm the cold air by turbulent mixing. Thickness (fig 53) leans towards "no snow" with values well above 5400 gpm. Despite strong winds, southwestern Germany received freezing precipitation on 18 Dec (fig 54) from the warm front. The strong winds did not remove the cold air. The progress of the warm front was delayed and the trailing cold front merged with the warm front forming a warm frontal occlusion, and this changed the freezing precipitation into snow. It is the same mechanism as described in case 8. However, further turbulent mixing after the cold frontal passage caused a weak thaw. The 18 Dec 12Z analysis shows the position of the cold front. The warm front has disappeared.

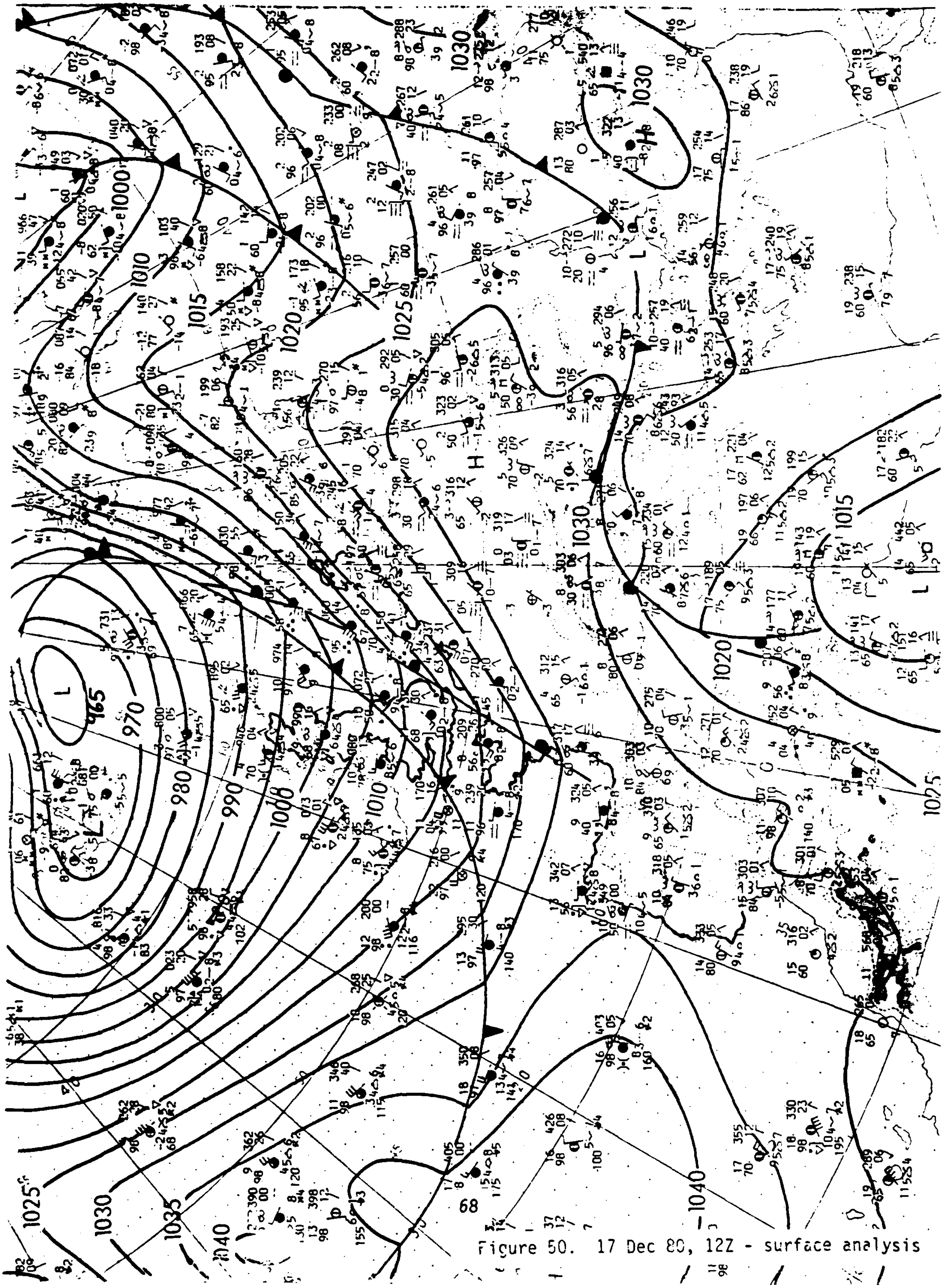

Figure 50. 17 Dec 80, 12Z - surface analysis

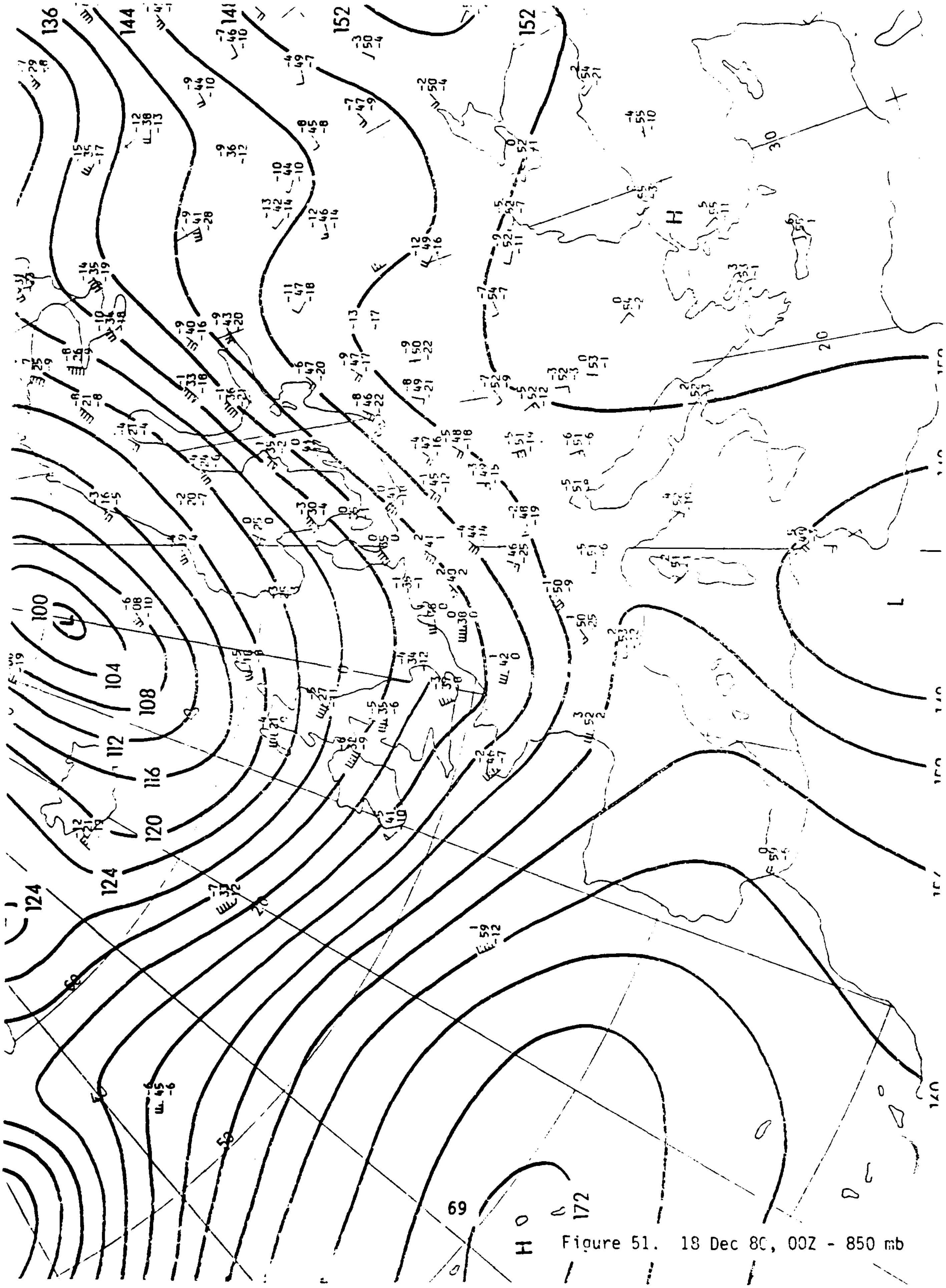

Figure 51. 18 Dec 80, 00Z - 850 mb

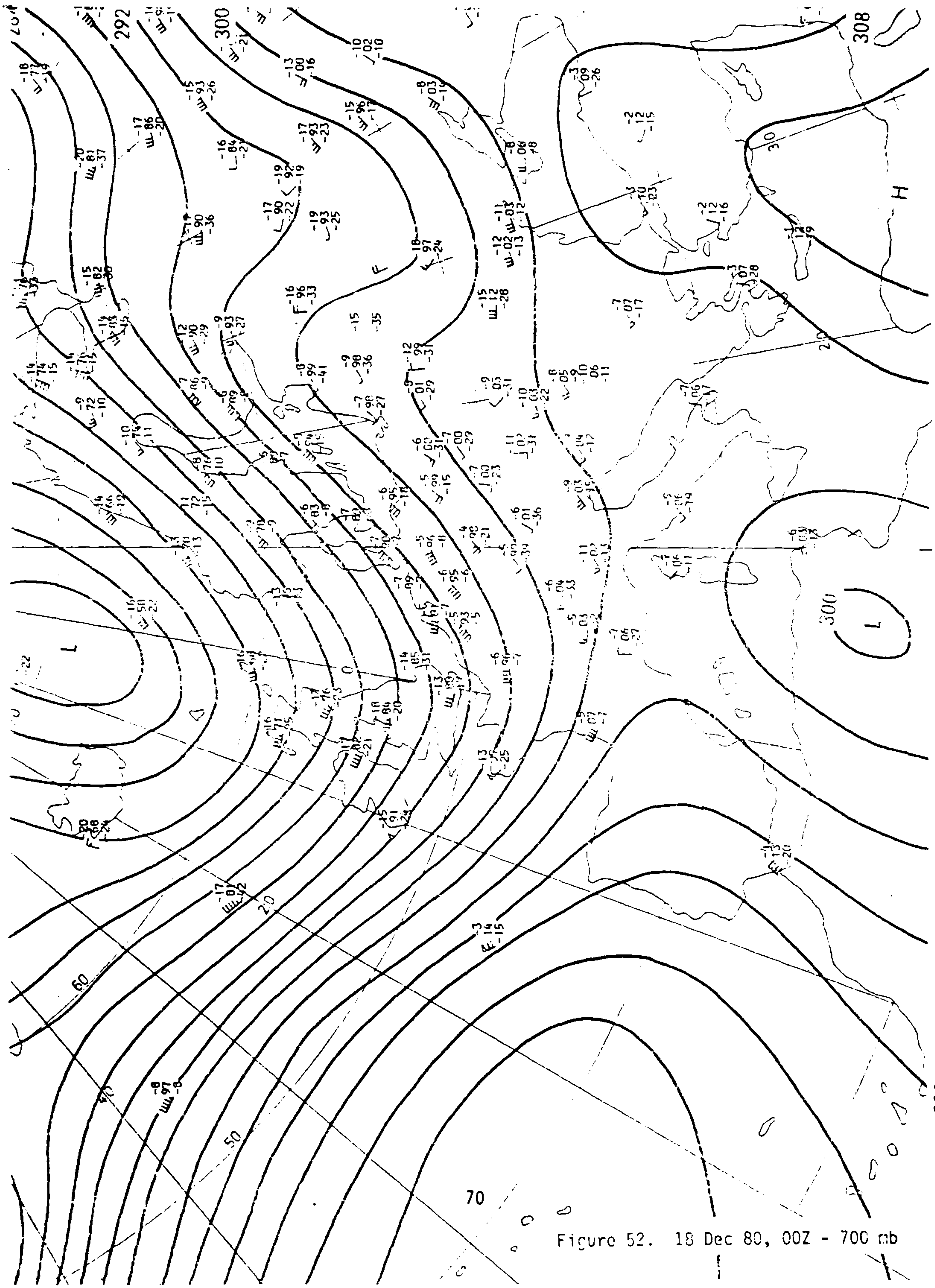

Figure 52. 18 Dec 80, 00Z - 700 mb

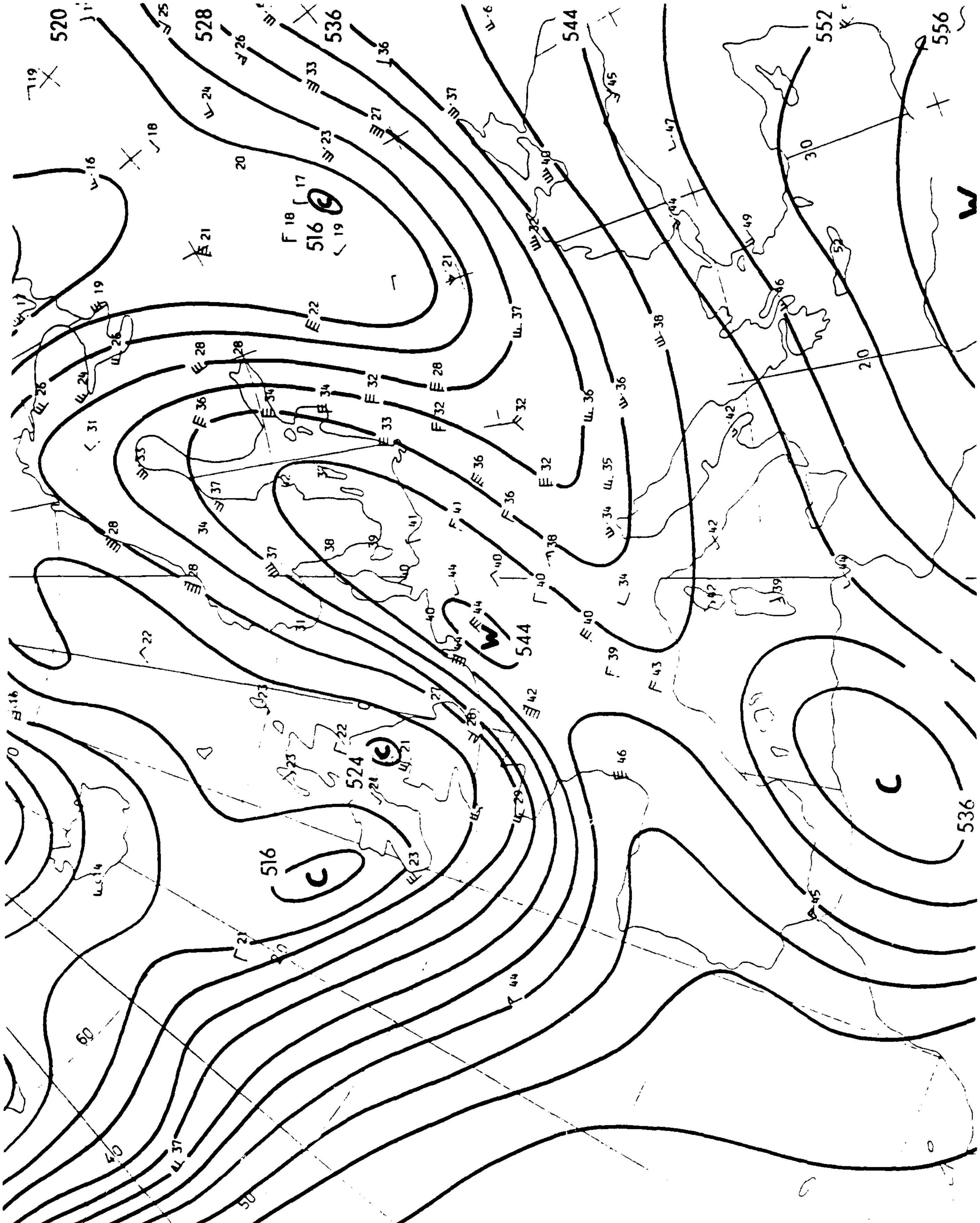

Figure 53. 18 Dec 80, 00Z - 1000-500 mb thickness

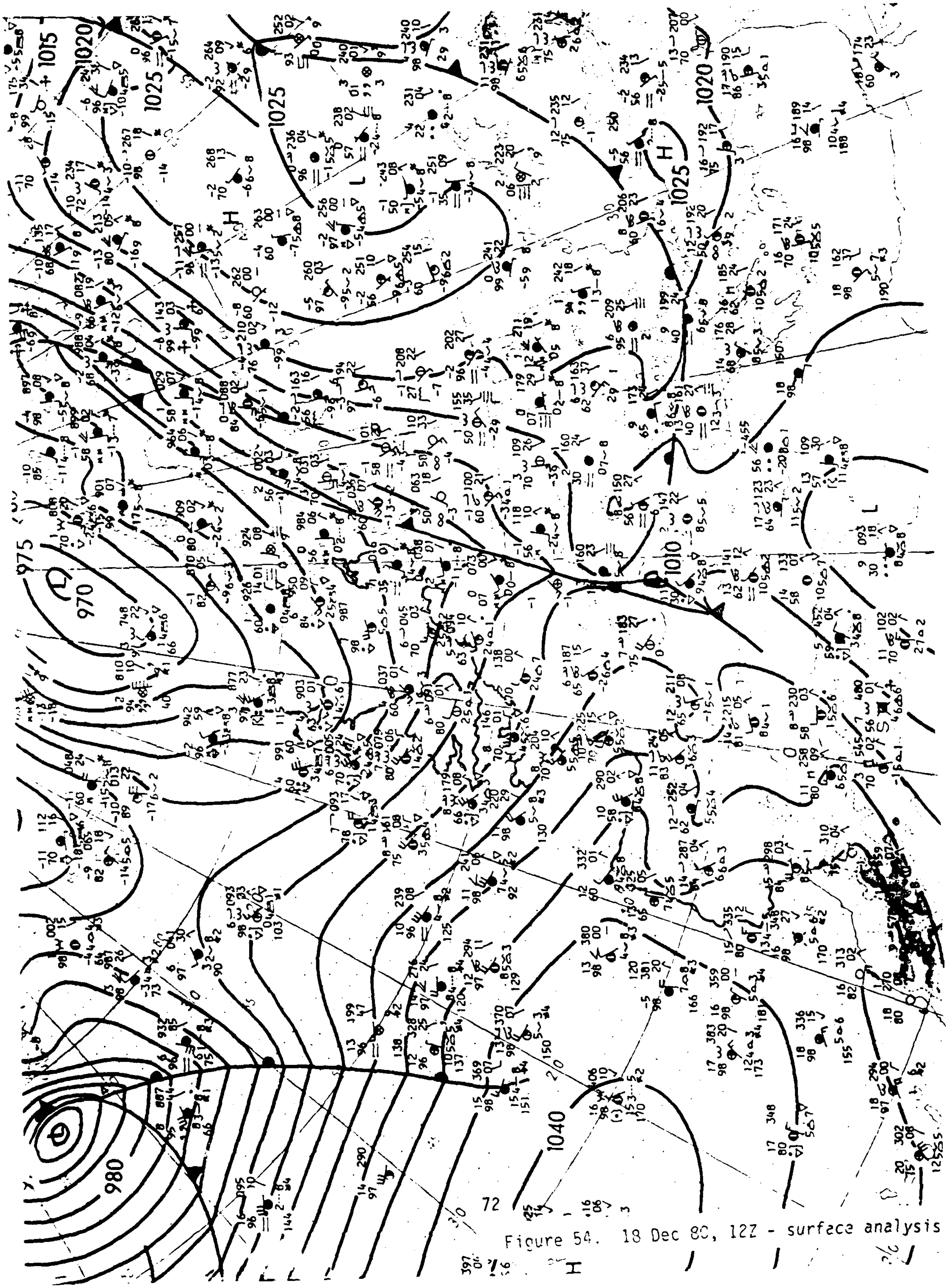

Figure 54. 18 Dec 80, 12Z - surface analysis

CASE 10. New Year's 1981. Real severe weather. The following situation is more of a typical winter storm than a common freezing precipitation event. It is included here because it brought freezing precipitation to Ramstein and Zweibruecken and no place else. On 31 Dec 80, at 12Z (fig 55), a complex low pressure system covers a large area of the north Atlantic Ocean, the Norwegian Sea, Scandinavia, and northwest U.S.S.R. A quasi-stationary front extends west-southwestward from Lithuania along the Baltic and North Sea coast into southwestern England. A cold front is moving southeastward over the North Sea and the central U.K. France and southern Germany are under the influence of the Azores High with upper level flow becoming northwest. The fronts were forecast to traverse Germany on New Year's day. Surface temperatures are above freezing everywhere except in central France. However, clear skies and southwesterly winds are causing temperature to drop below freezing in southern Germany, chiefly because the southwesterly winds are not advecting warmer air into Germany. At 00Z on 1 Jan 81, the warm front is crossing southwest Germany with 850 mb winds of 40-45 knots and temperatures of -1°C to +1°C (fig 56). Thinking that the high winds will warm the subfreezing temperatures when the frontal clouds arrived is wrong (see previous case). The rain began (850 mb temperature greater than -1°C) while the lowest layers were still frozen, hence freezing precipitation. Why? Winds are westerly, which is upslope at Ramstein and Zweibruecken, but are downslope in the Rhine Valley west of the Rhine, neutral at Rhein-Main and generally downslope east of the Black Forest. The winds are turning more towards the northwest which is also downslope at Bitburg and Spangdahlem. Hahn cannot receive freezing precipitation because it is located above the cold air and has gusty winds which indicate strong turbulence. However, this time the turbulent mixing of the atmosphere removed the subfreezing temperatures after 1-2 hours, so that the freezing precipitation turned into rain. This was just before the cold front passed with high winds, hailshowers, and sleet (850 mb temperature colder than -3°C, 700 mb colder than -10°C). The surface analysis on 1 Jan 81, 12Z (fig 59) shows the cold front along the northern side of the Alps, a strong northwesterly flow over central Europe, and showers, chiefly with small hail, sleet or snow. The cold frontal passage brought 50-60 knot gusts over the Netherlands, Belgium, and northern Germany together with heavy showers and thunderstorms. Bottom line: Although severe winter weather may arrive, remember to think about areas where freezing precipitation may occur.

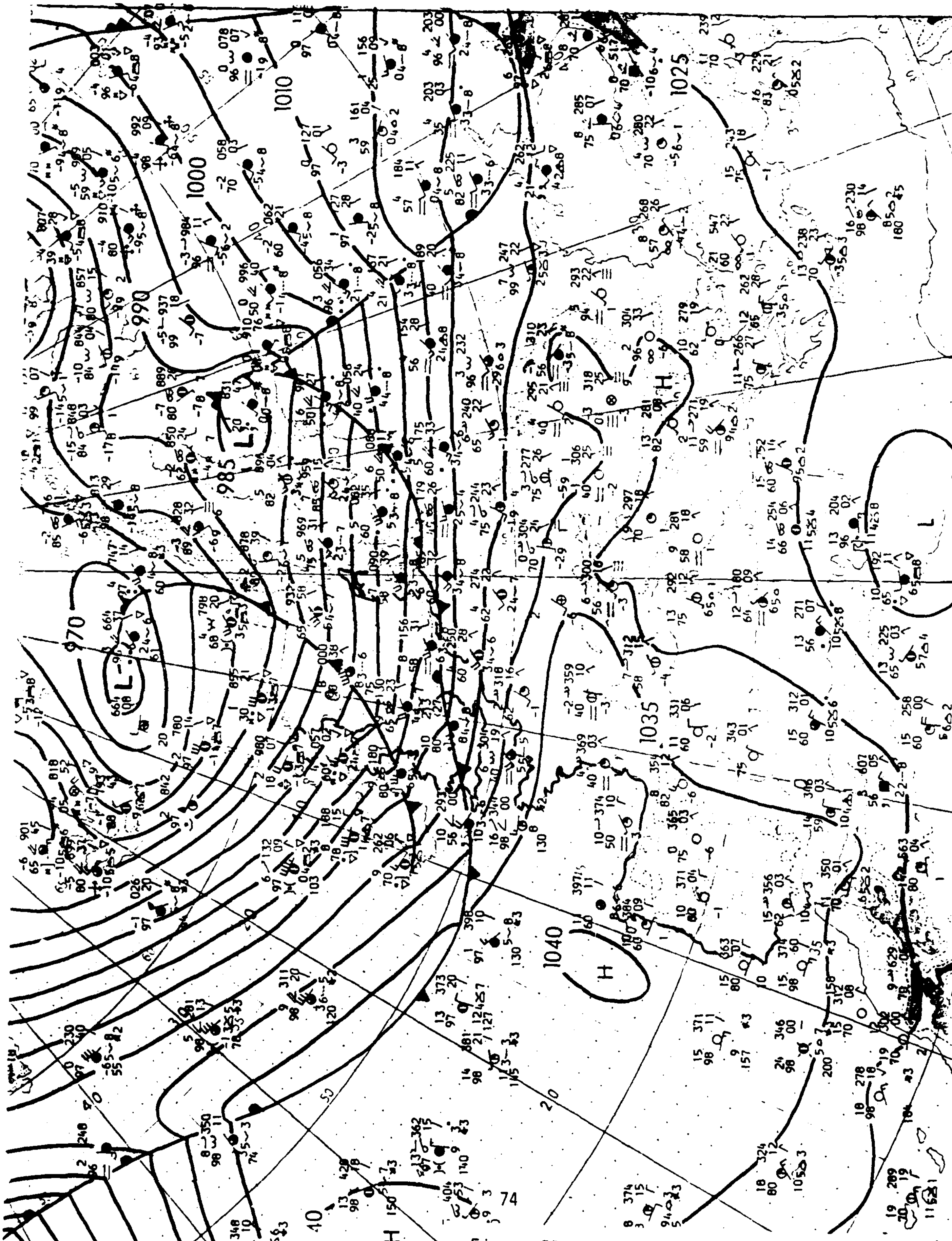

Figure 55. 31 Dec 80, 12Z - surface analysis

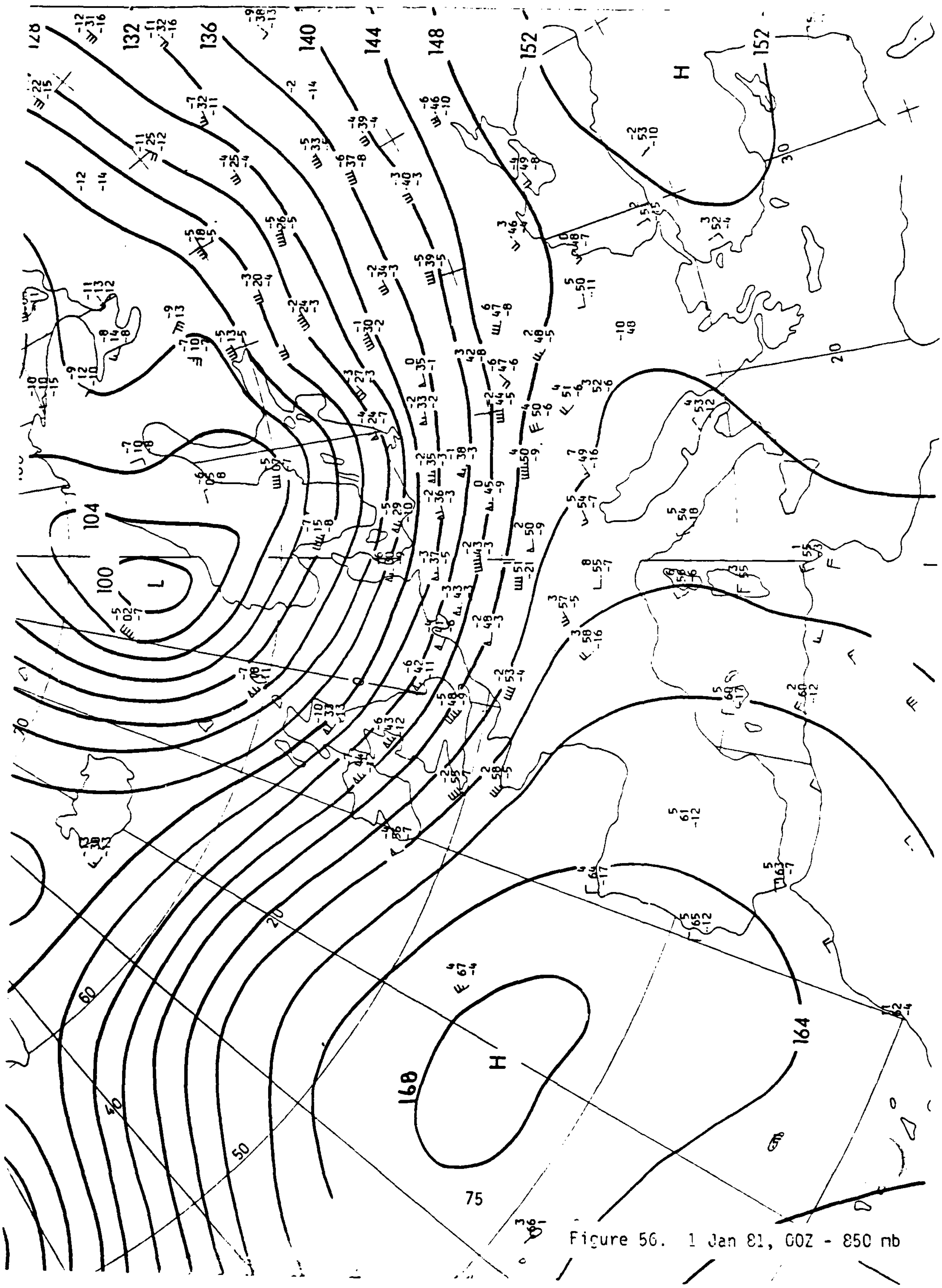

Figure 56. 1 Jan 81, 00Z - 850 mb

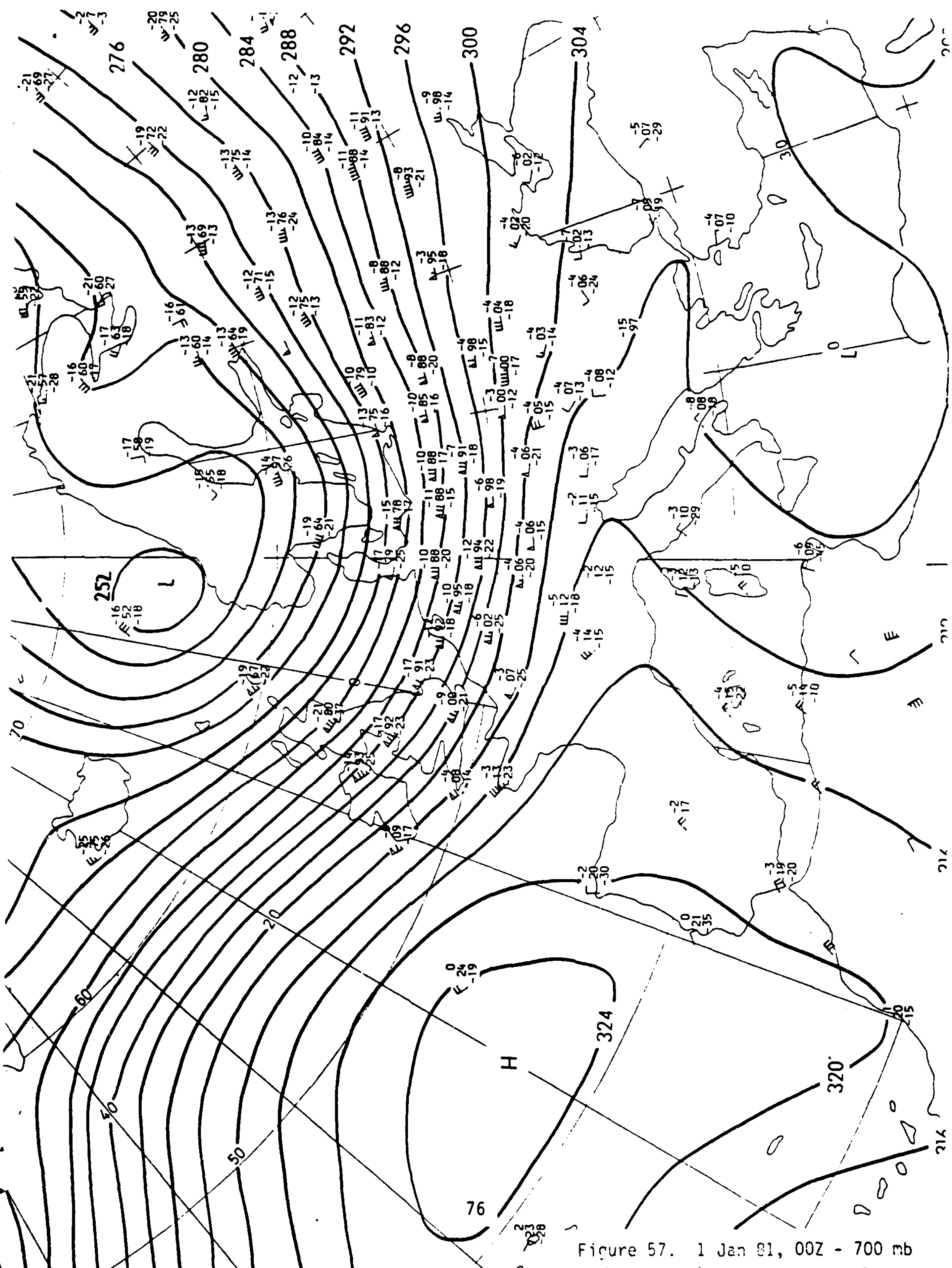

Figure 57. 1 Jan 81, 00Z - 700 mb

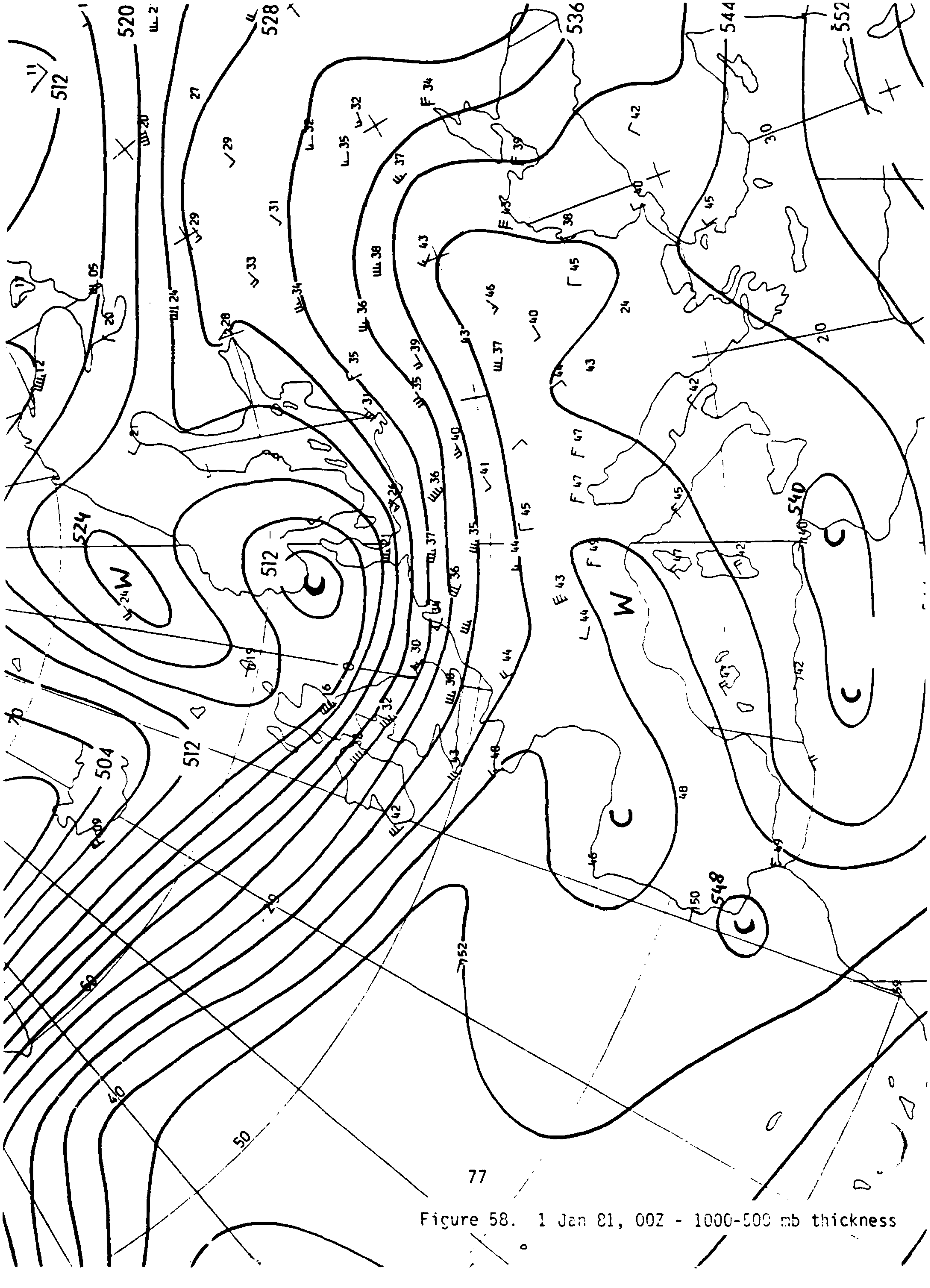

Figure 58. 1 Jan 81, 00Z - 1000-500 mb thickness

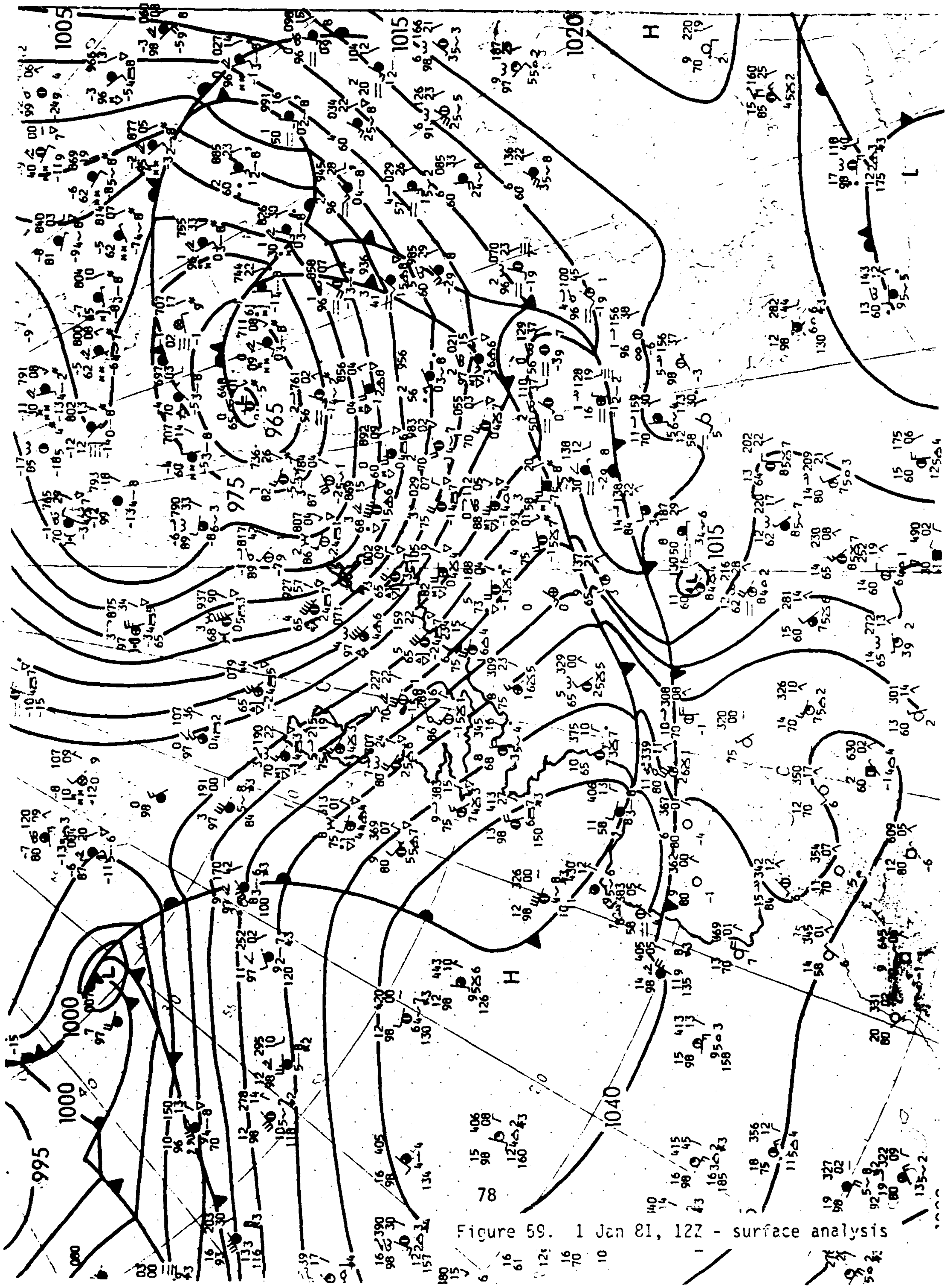

Figure 59. 1 Jan 81, 12Z - surface analysis

CASE 11. 7-9 January 1979. The end of an unusual cold spell. The synoptic situation on 7 Jan 79, 12Z (fig 60), is not much different from that of 17 Dec 80 - (see case 9) and 8 Jan 81 (see case 8). A complex low pressure system covers the Norwegian Sea and a high is centered over Hungary, giving anticyclonic flow to southern Germany and France. Over the area, temperatures are unusually cold, Rhein-Main has -9°C and Paris -7°C. Even Rotterdam has subfreezing temperatures. Freezing precipitation in Denmark under southwesterly flow is indeed a rare event. Southwesterly flow over the Benelux is bringing cold air from France into the coastal areas and freezing precipitation is occurring at Soesterberg. Applying the temperature at 850 mb (fig 61), 700 mb (fig 62), and 1000-500 mb thickness (fig 63) to Table 2 in Section IV, correctly rules out snow. The problem is strong winds, 30-35 knots at 850 mb, which should be strong enough to displace, under normal conditions, any cold air over the coastal areas and the flat lands of northern Germany. But the key factor is conditions are not normal. The surface analysis of 8 Jan 12Z (fig 64) still shows the problem: temperatures barely above freezing along the North Sea coasts from Belgium into Denmark, a warm front dissipating on the foothills of the Ardennes and Eifel-Sauerland-Harz Mountains, and two cold fronts over the U.K. oriented east-southeast. Note that temperatures in northern France are still below freezing. By 9 Jan 79 things begin to change. The approaching cold front is lowering temperatures at 850 mb (fig 65) from near freezing to -4°C and at 700 mb (fig 66) from -8°C to -12°C, which means precipitation should be snow. Freezing precipitation is occurring over southwestern Germany with the warm air aloft and surface temperatures between -5°C and -10°C. The analysis on 9 Jan, 12Z (fig 68) shows a cold front over the Eifel and Ardennes mountains stretching southwestward into the Bay of Biscaye. Temperatures are now rising. Rhein-Main is only -2°C, but with freezing precipitation. Rain or snow is falling in the north since turbulent mixing is finally warming the cold air. South of the Eifels though, the subfreezing temperatures prevail as a cold front passes and deposits new snow over the ice. Exactly 2 years later (see case 8), northerly to northeasterly flow did the same thing in southern Germany.

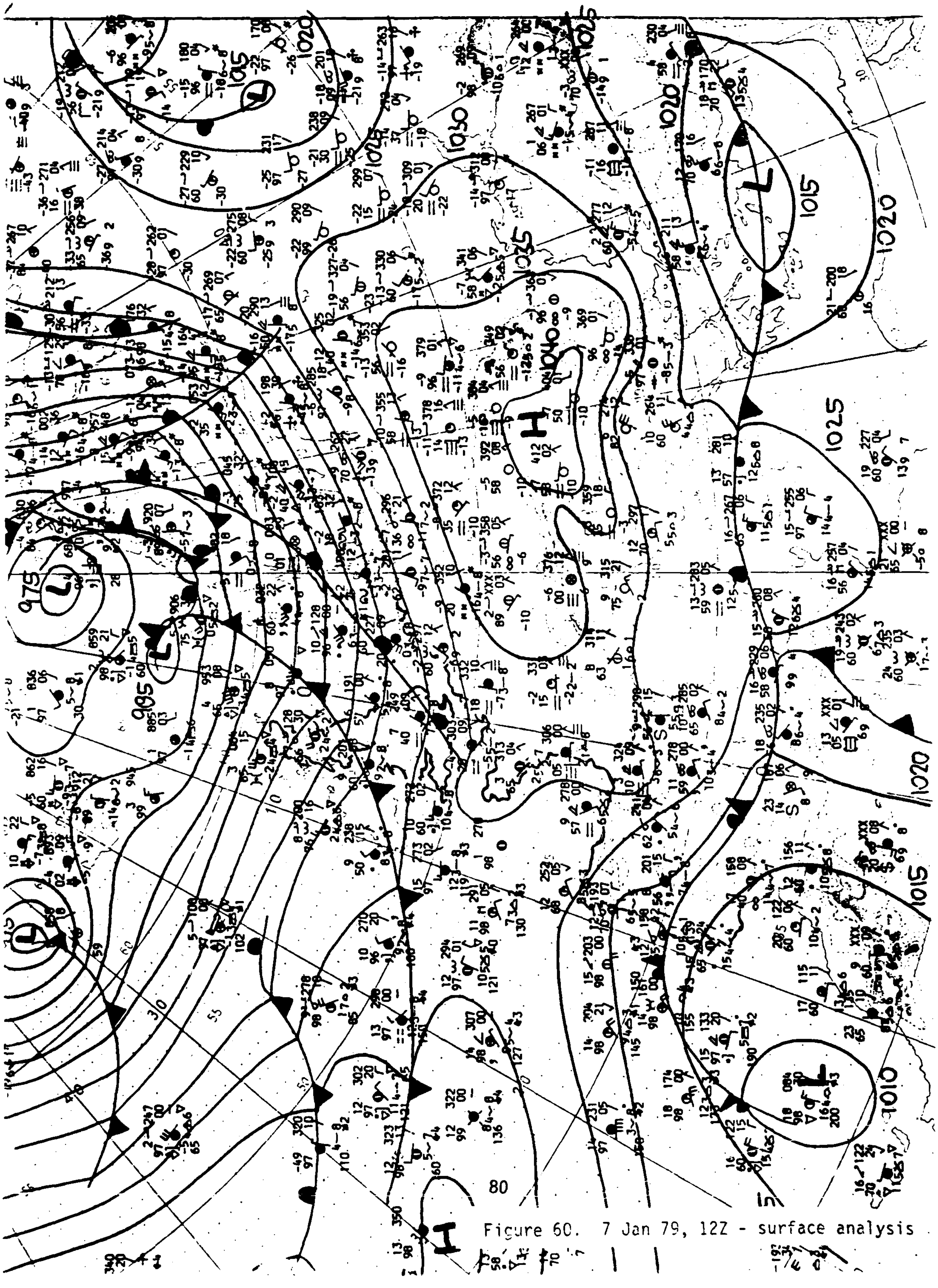

Figure 60. 7 Jan 79, 12Z - surface analysis

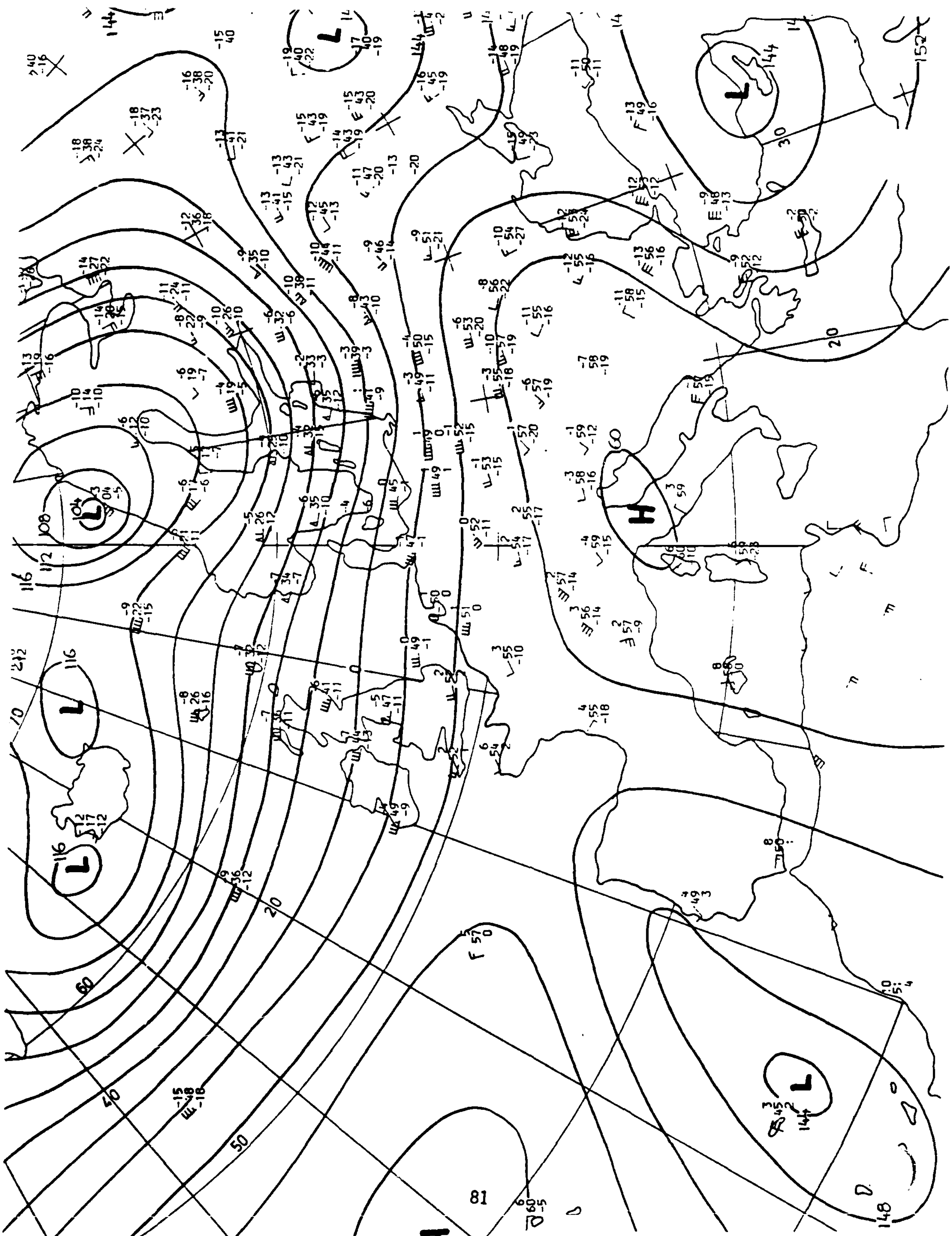

Figure 61. 8 Jan 79, 00Z - 850 mb

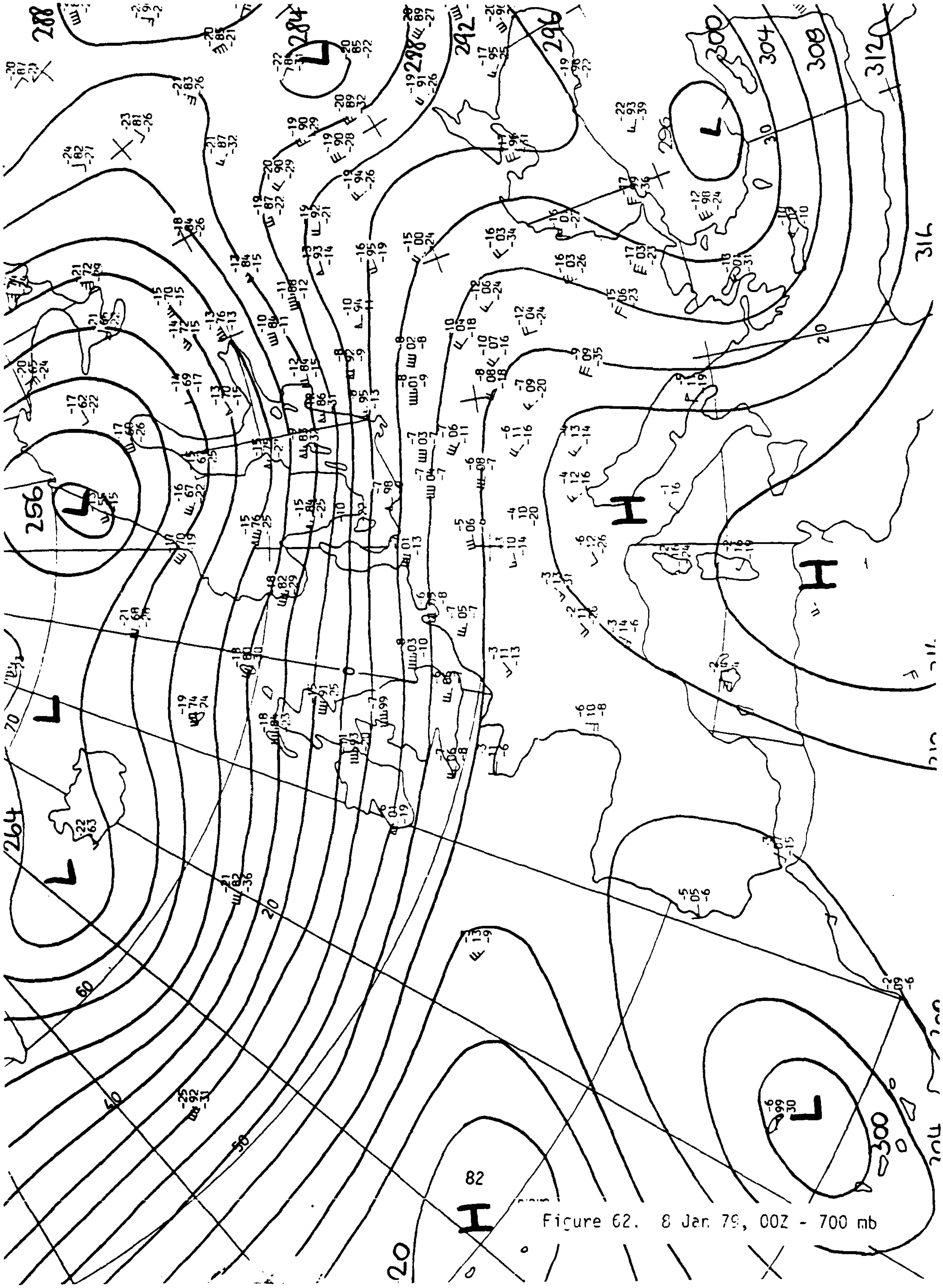

Figure 62. 8 Jan 79, 00Z - 700 mb

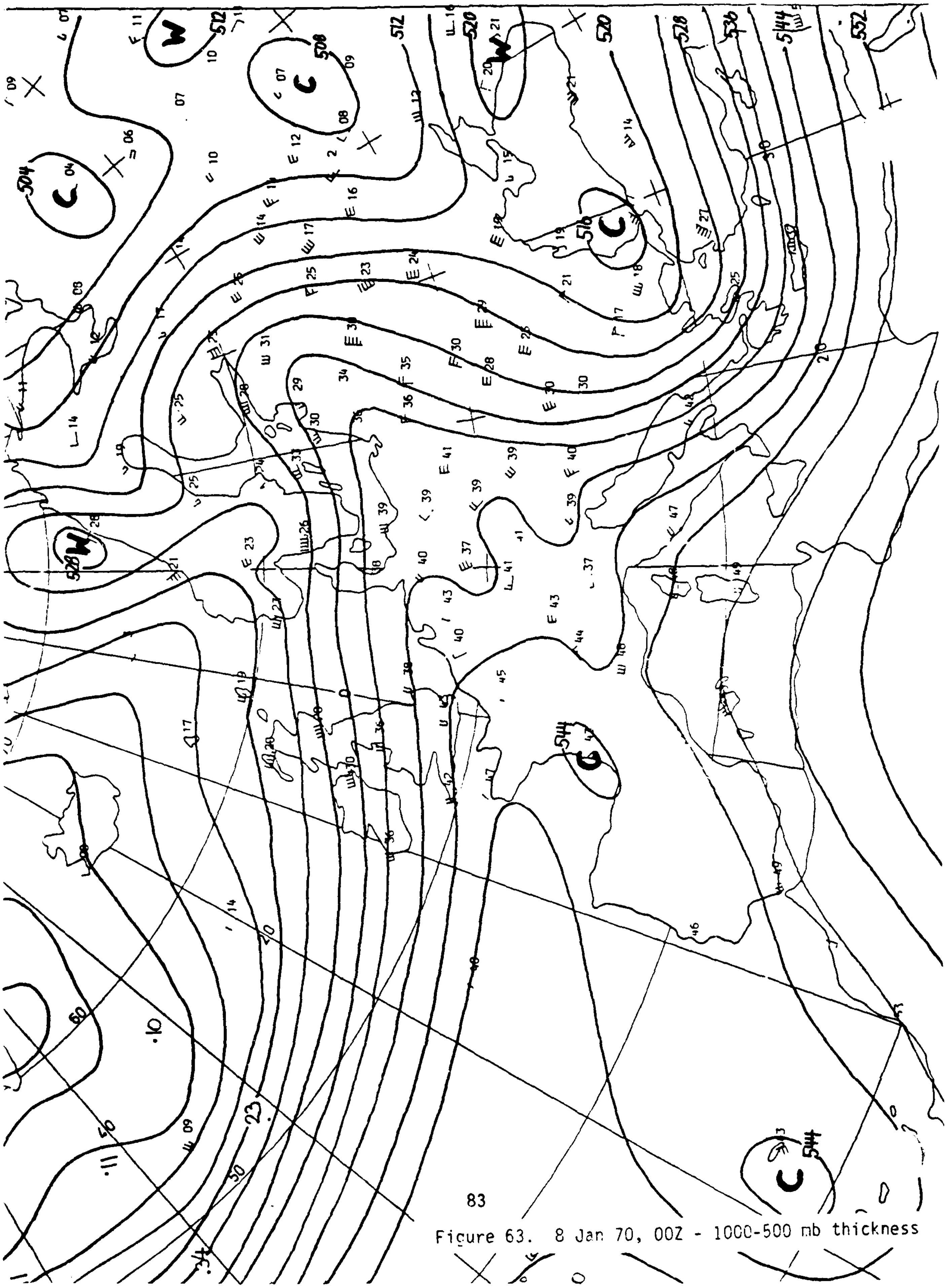

Figure 63. 8 Jan 70, 00Z - 1000-500 mb thickness

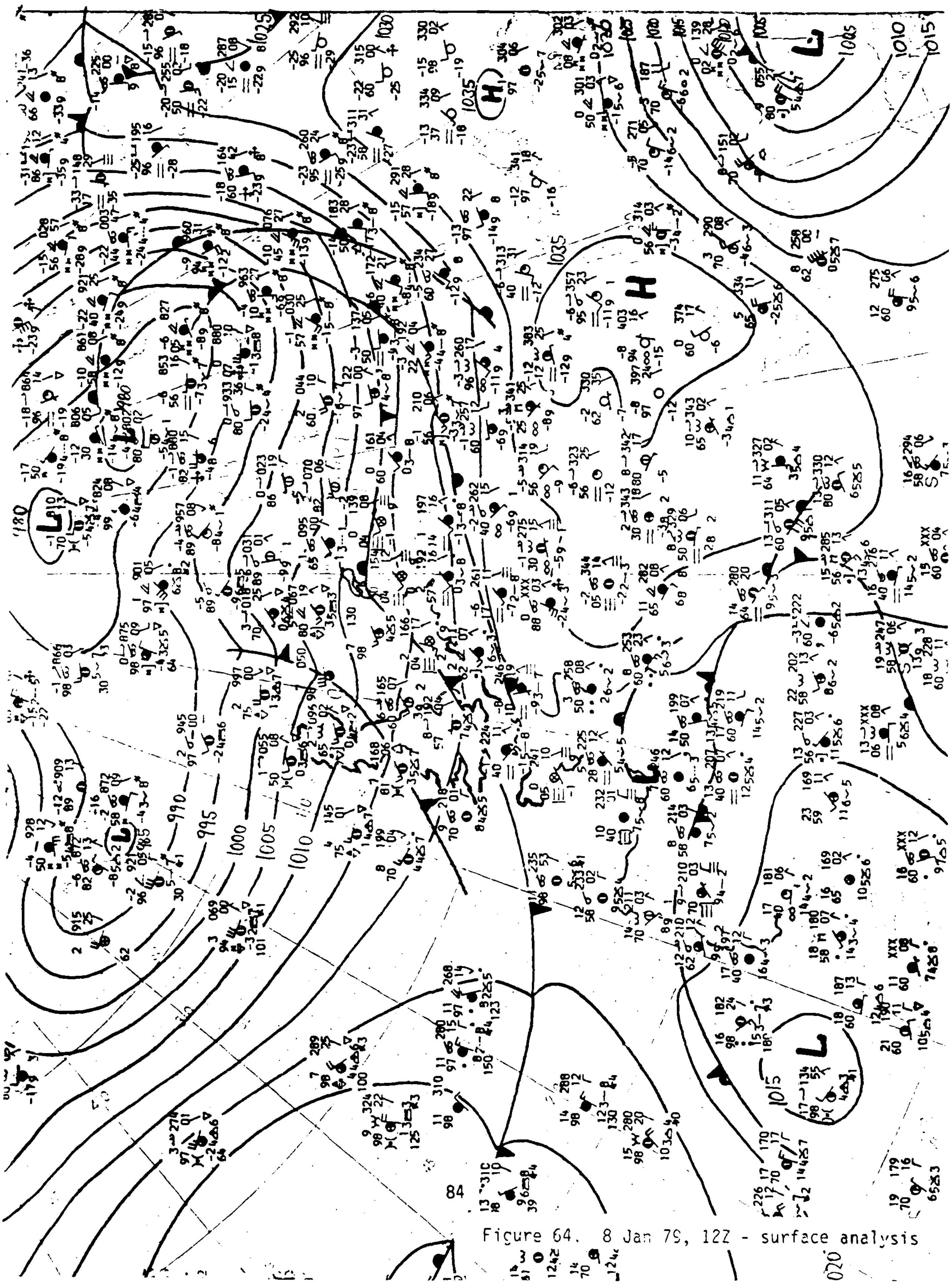

Figure 64. 8 Jan 79, 12Z - surface analysis

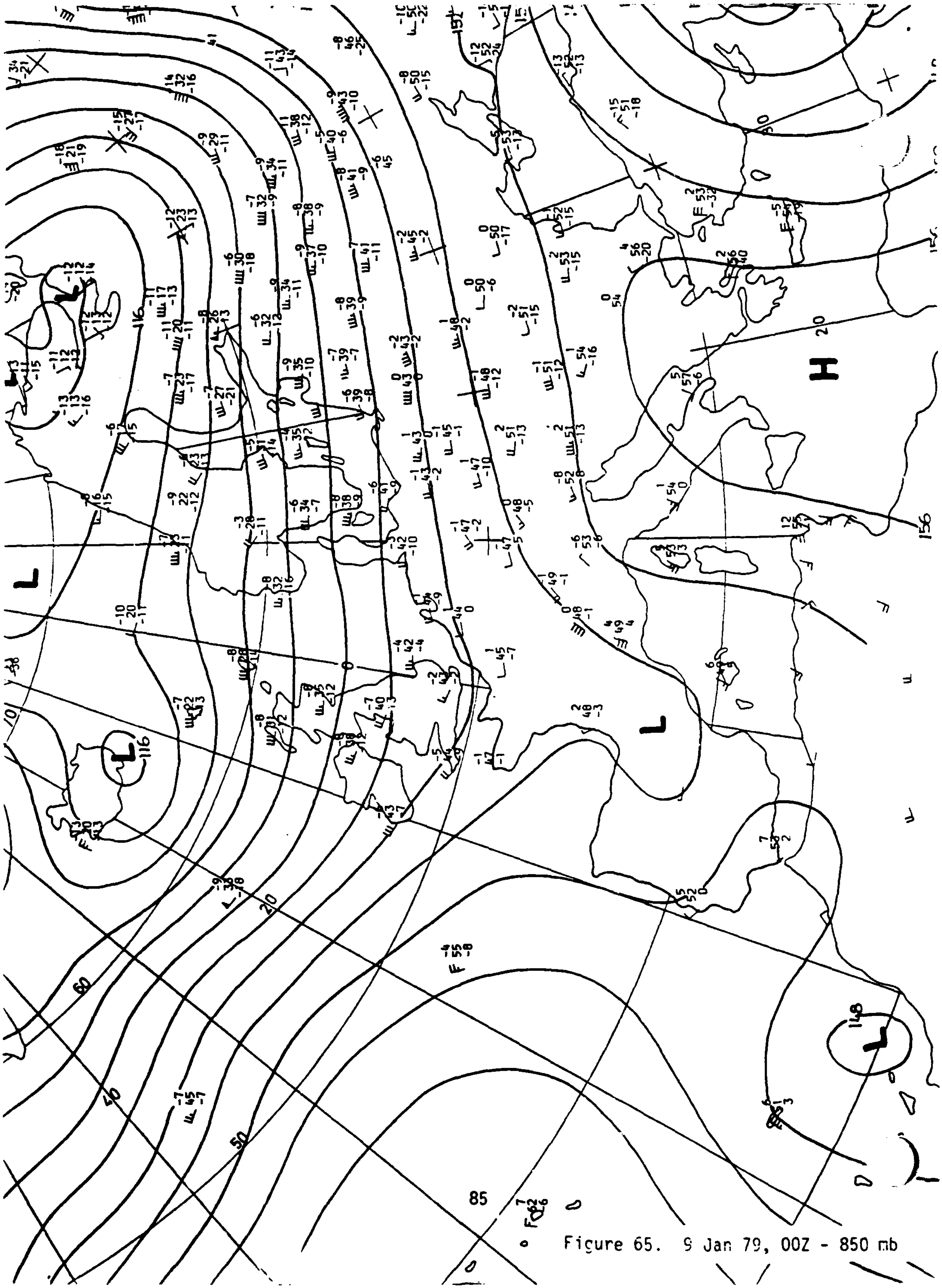

Figure 65. 9 Jan 79, 00Z - 850 mb

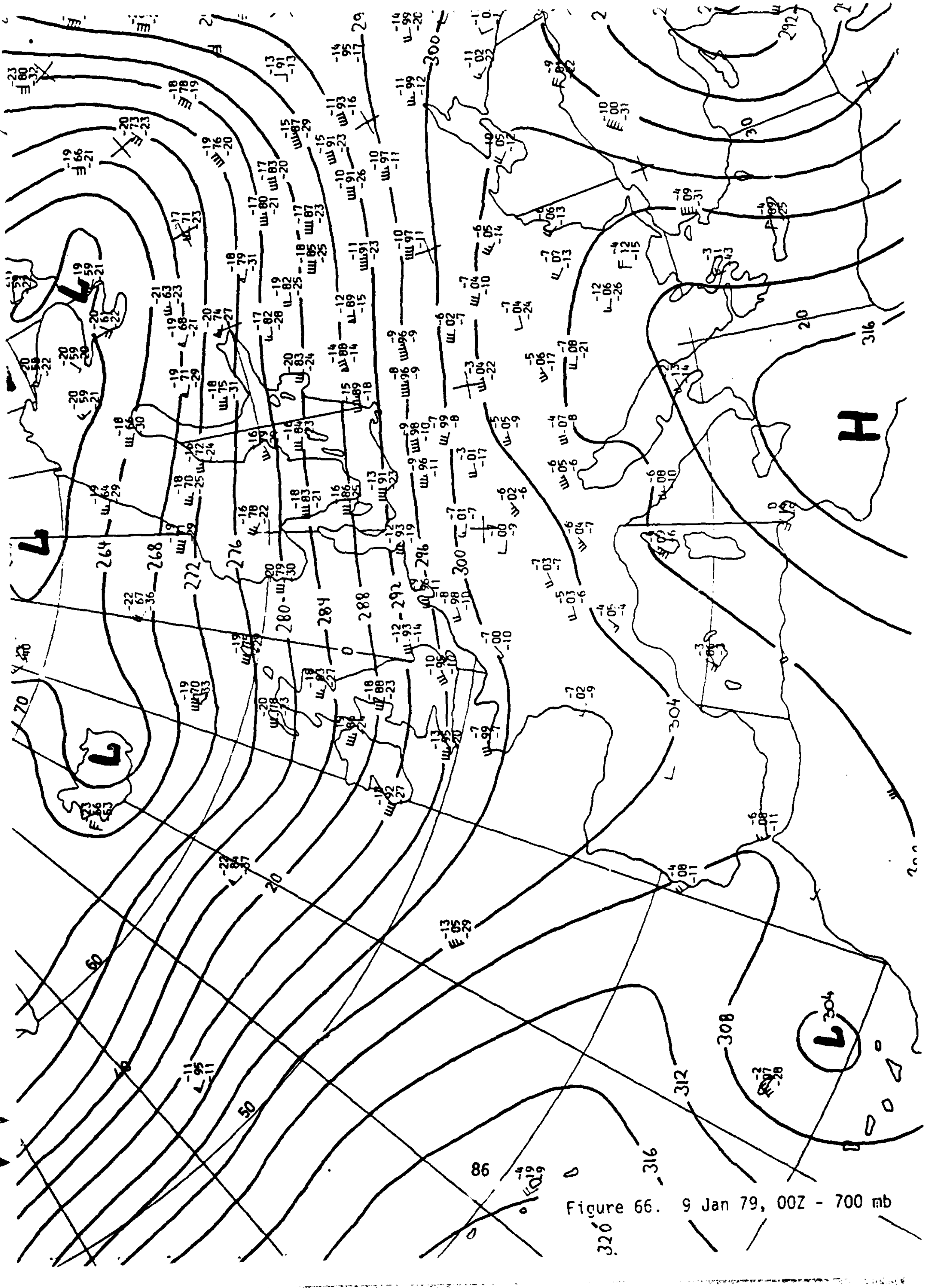

Figure 66. 9 Jan 79, 00Z - 700 mb

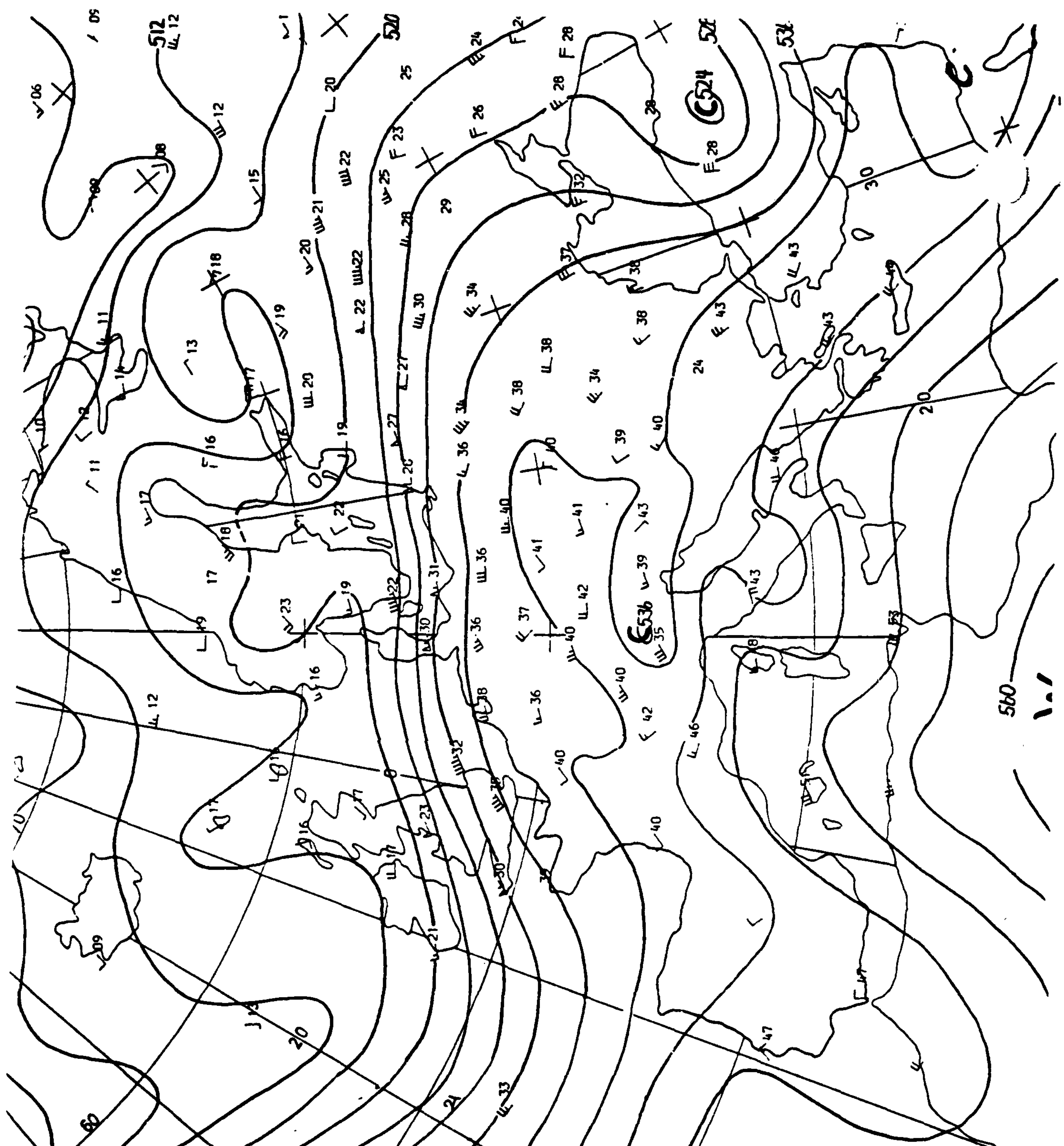

Figure 67. 9 Jan 79, 00Z - 1000-500 mb thickness

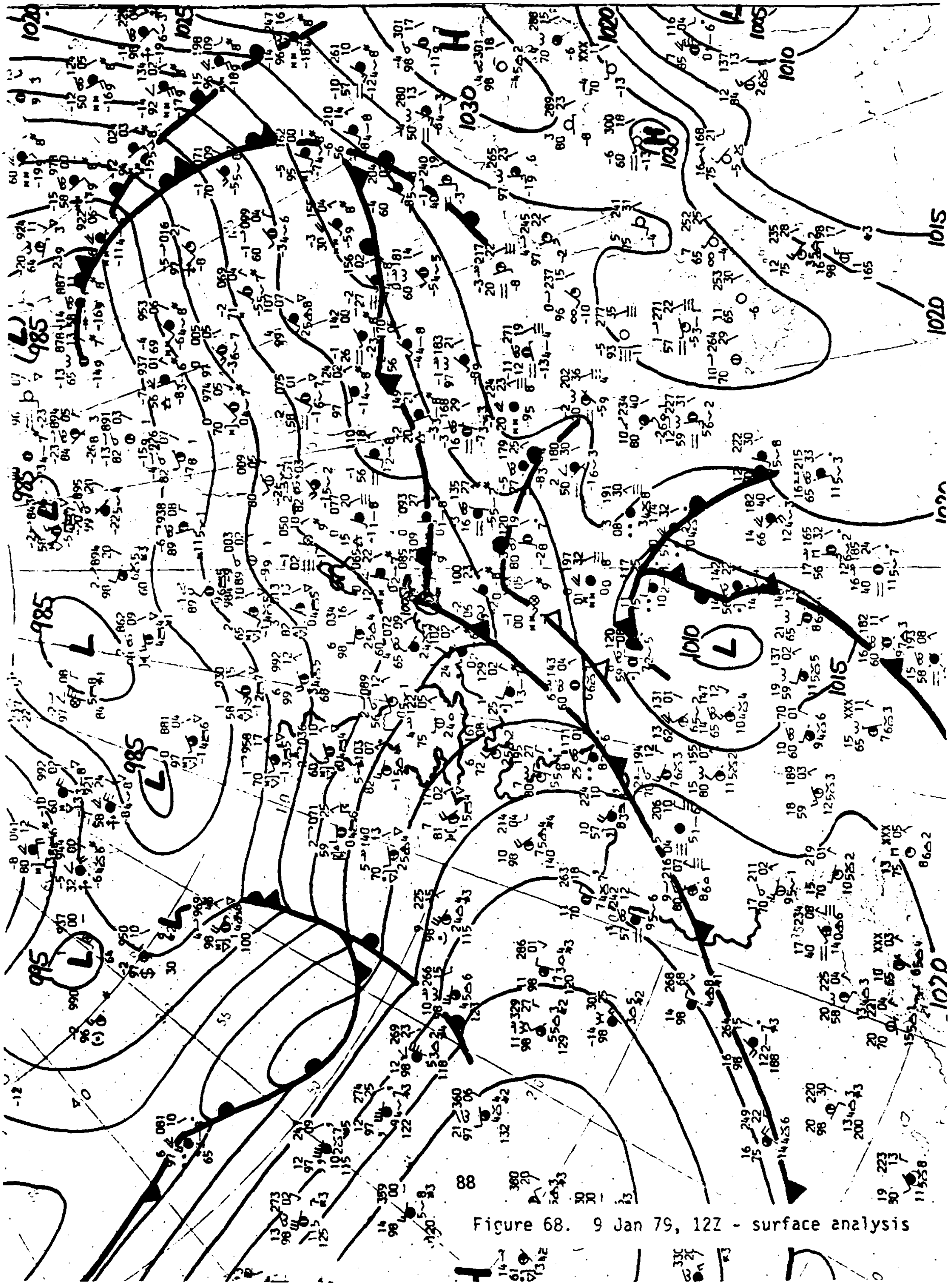

Figure 68. 9 Jan 79, 12Z - surface analysis

CASE 12. 6 November 1980. An unusually early event. Early November is not normally the time for real winter weather, but November 1980 started out very cold. Parts of southwestern Germany already had some snow cover and an easterly flow with bitter cold winds brought Siberian air far into western Europe (fig 69). An occluded front stretches east-west just south of 50°N, directly over Ramstein AB, where freezing precipitation was observed. The same front brought snow over northern France. The reason is not easily seen. Temperatures at 850 mb (fig 70) vary between -4°C and -8°C (only Essen reported -1°C) but at 700 mb (fig 71), temperatures are between -1°C and -4°C, well above the -6°C threshold in Table 2. The plotted radiosonde data from Stuttgart and Munich (WMO #10868 and 10739, fig 72) provides further insight. Temperatures are above freezing between 840 and 710 mb, a typical layer for overrunning of Mediterranean air from the southeast (by way of Yugoslavia). This trajectory is apparent at 700 mb. Again, terrain modifies the conditions. The overrunning loses strength causing temperatures to remain below freezing; hence, to the north the little precipitation that did fall was snow. Bottom line: Freezing rain can come from the southeast i.e., from over the continent. Look for returning Mediterranean air.

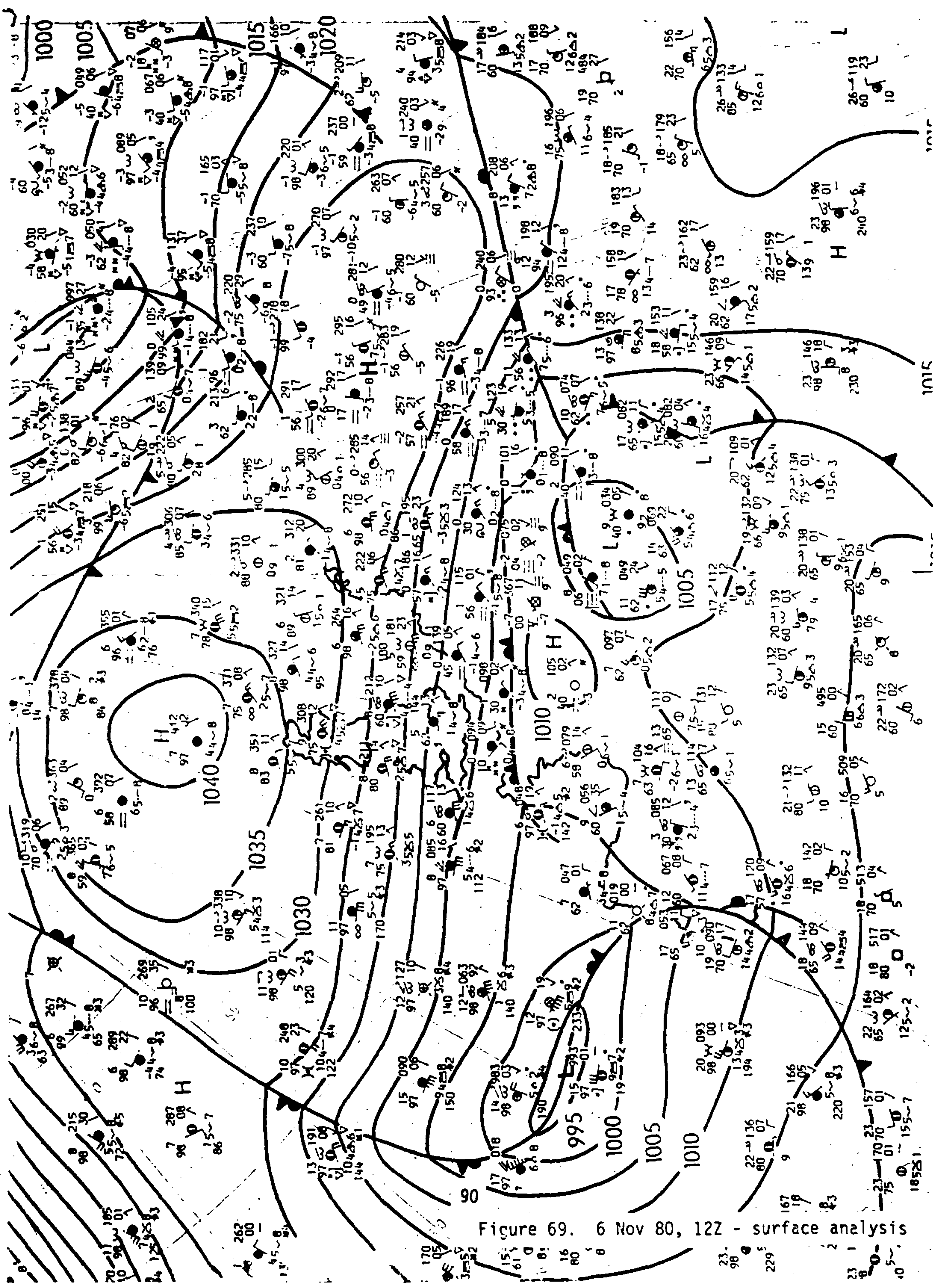

Figure 69. 6 Nov 80, 12Z - surface analysis

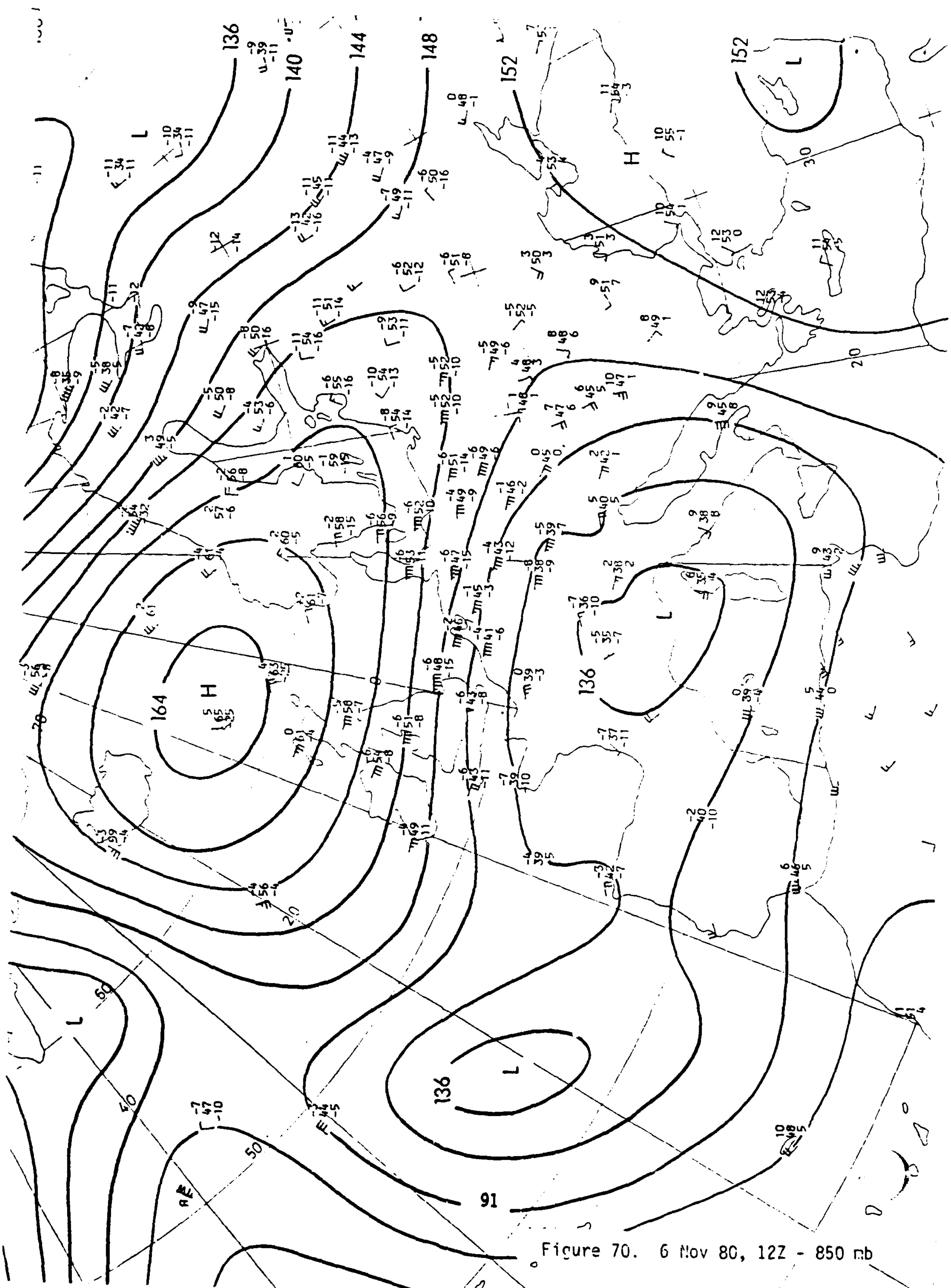

Figure 70. 6 Nov 80, 12Z - 850 mb

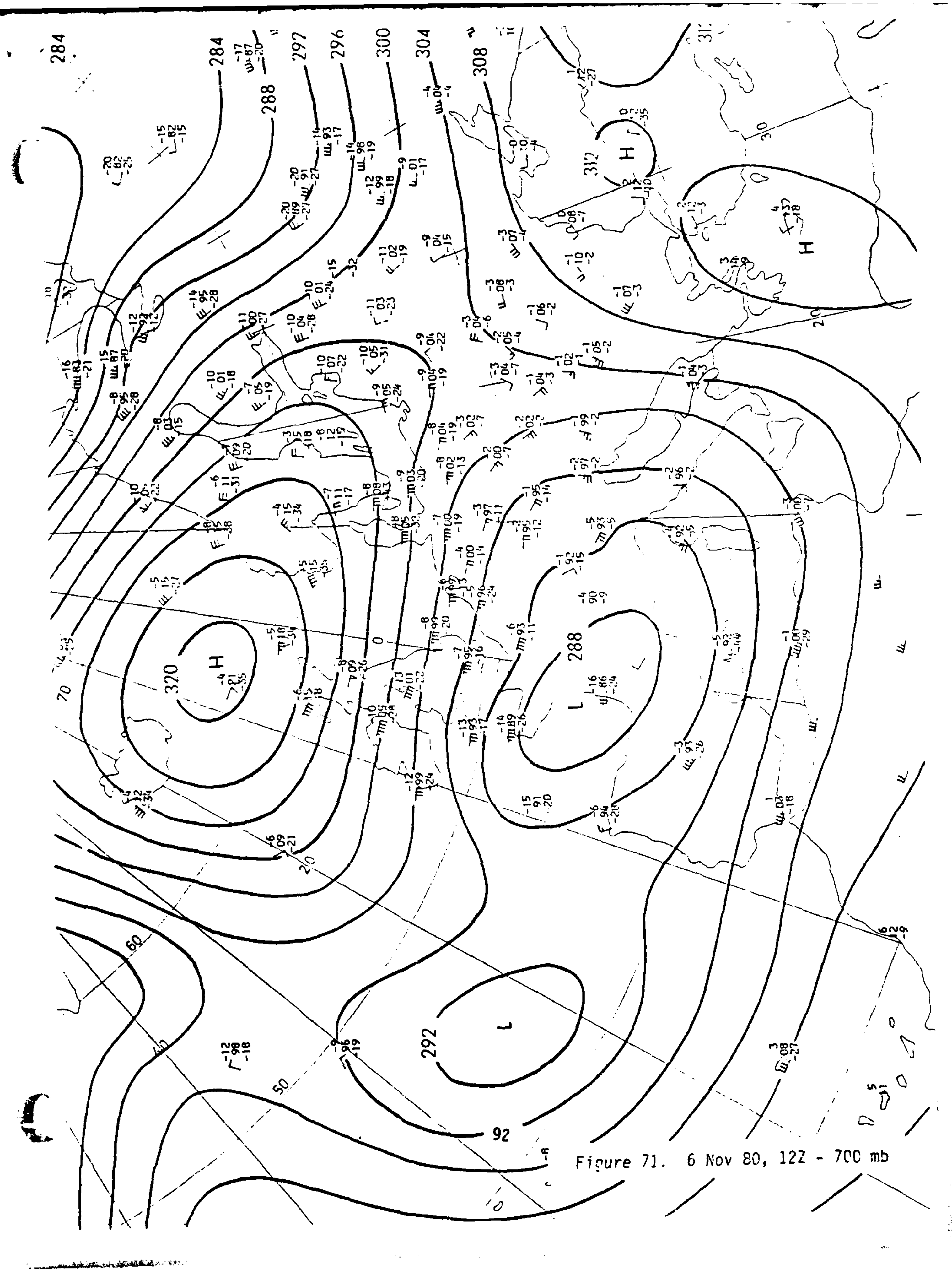

Figure 71. 6 Nov 80, 12Z - 700 mb

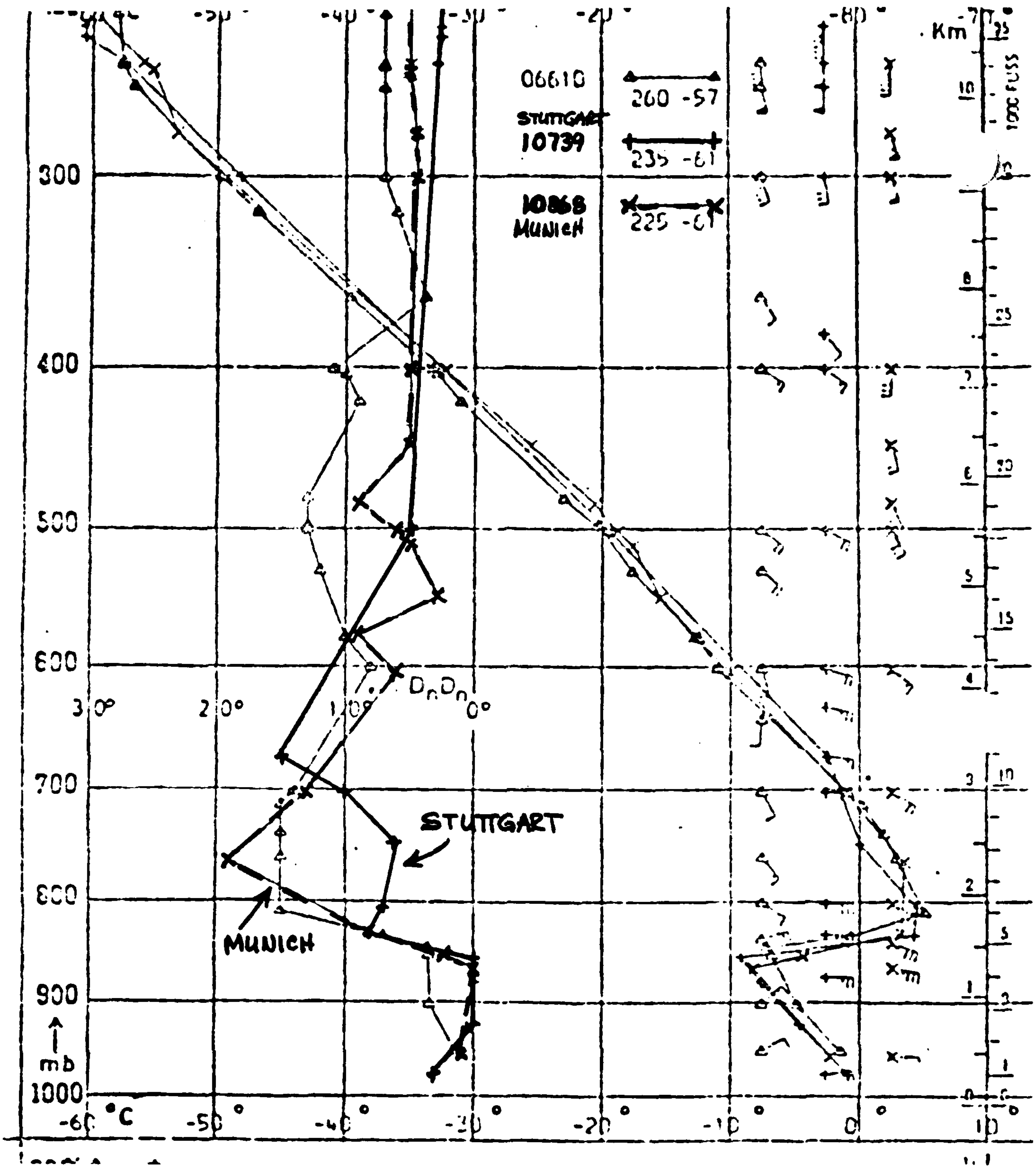

Figure 72. 6 Nov 80, 00Z, Stuttgart/Munich Radiosonde

CASE 13. 18-19 February 1982. It came from the northeast. Freezing precipitation from the northeast is not uncommon in the northeastern U.S. when Atlantic air is pushing westward before the polar air from the north breaks in. In Europe, such a pattern looks strange since the northeast is the area where the coldest air is expected. The situation on 18 Feb 82, 12Z (fig 73) shows a closed high over Scandinavia producing an easterly flow over central Europe. A cold front stretches from the interior U.S.S.R., over the Carpathians and the Harz Mountains to the North Sea coast. This location coincides with the northeastern flank of the central European mountainous area and gives the impression that the cold air behind is probably too shallow to cross these mountains. However, a quick look at the 700 mb chart from 19 Feb 00Z (fig 74) reveals the cold air is deeper than the height of the Harz or the Carpathians. Temperatures are -8° to $-10^\circ C$ in the west and near $-15^\circ C$ in the east, indicating a strong cold front. At 850 mb (fig 75) temperatures are -8° to $-11^\circ C$ in the east, but $-2^\circ C$ to $+2^\circ C$ in the west and southwest. The 19 Feb 00Z surface analysis (fig 76) shows a cold front between the Eifel Mountains and the Danube River with fog and drizzle. Lowering temperatures at the surface are causing the drizzle to freeze, but as the cold air reaches the 850 mb level the cloud deck begins to dissipate and the freezing drizzle ends without snow.

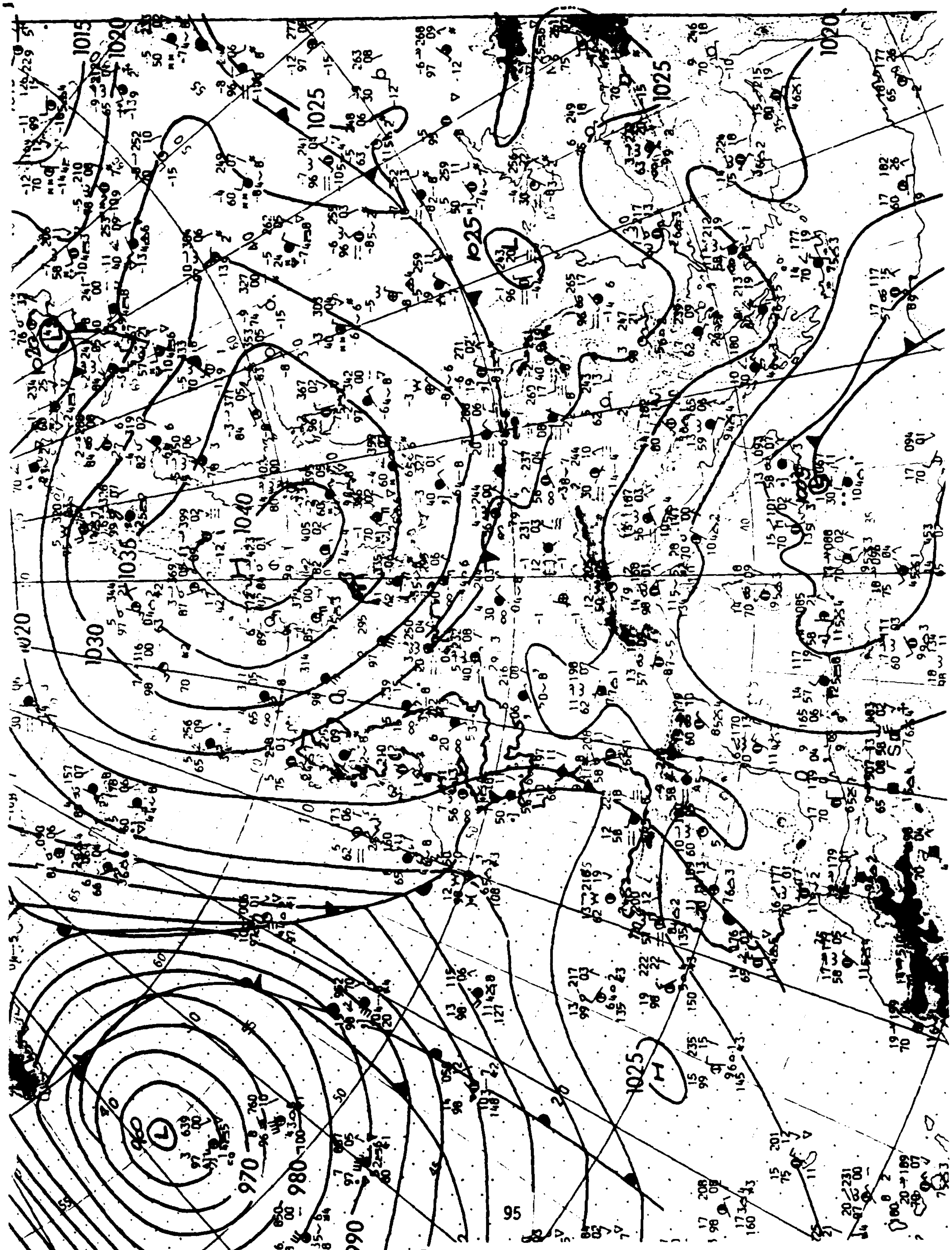

Figure 73. 18 Feb 82, 12Z - surface analysis

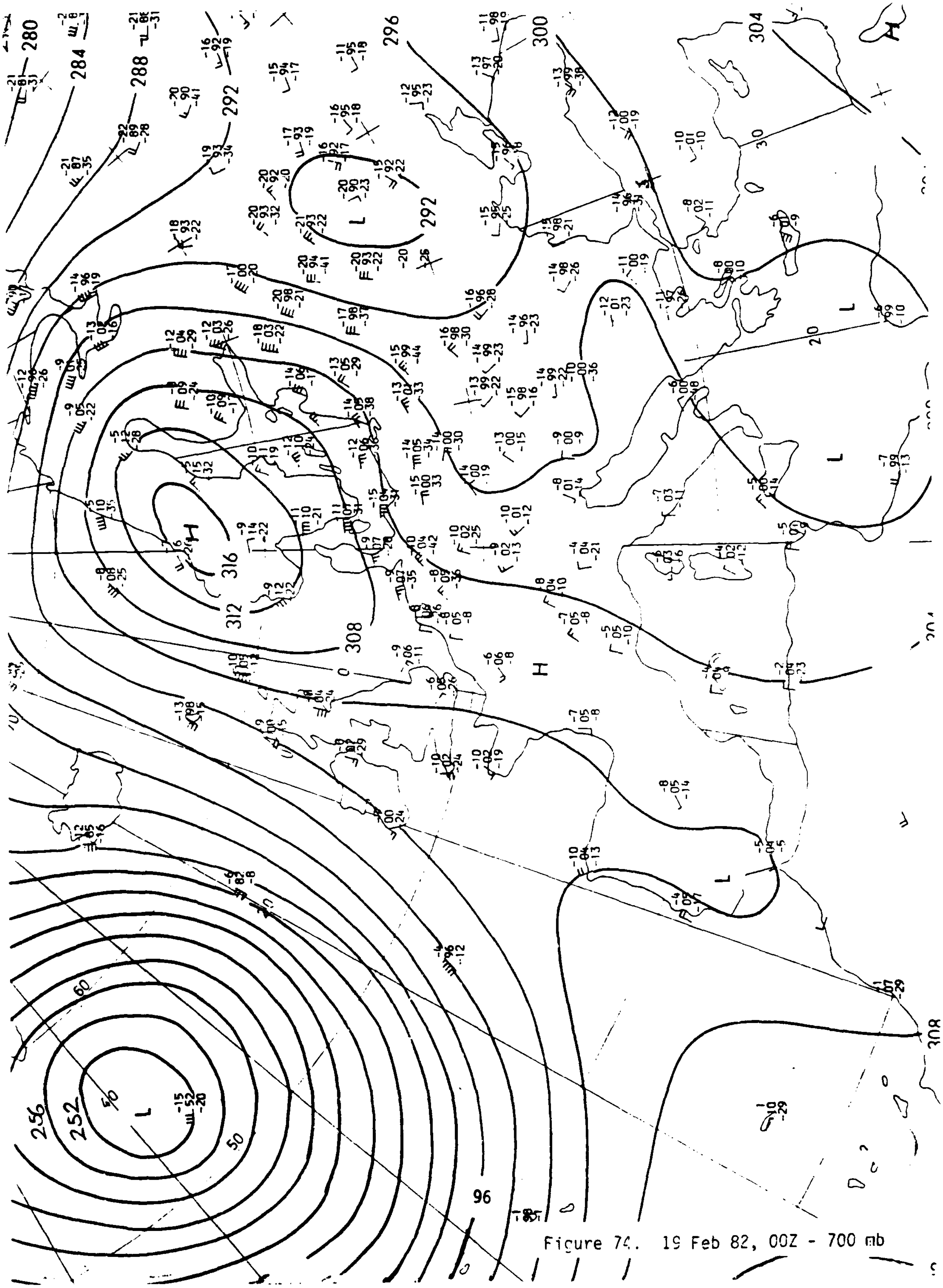

Figure 74. 19 Feb 82, 00Z - 700 mb

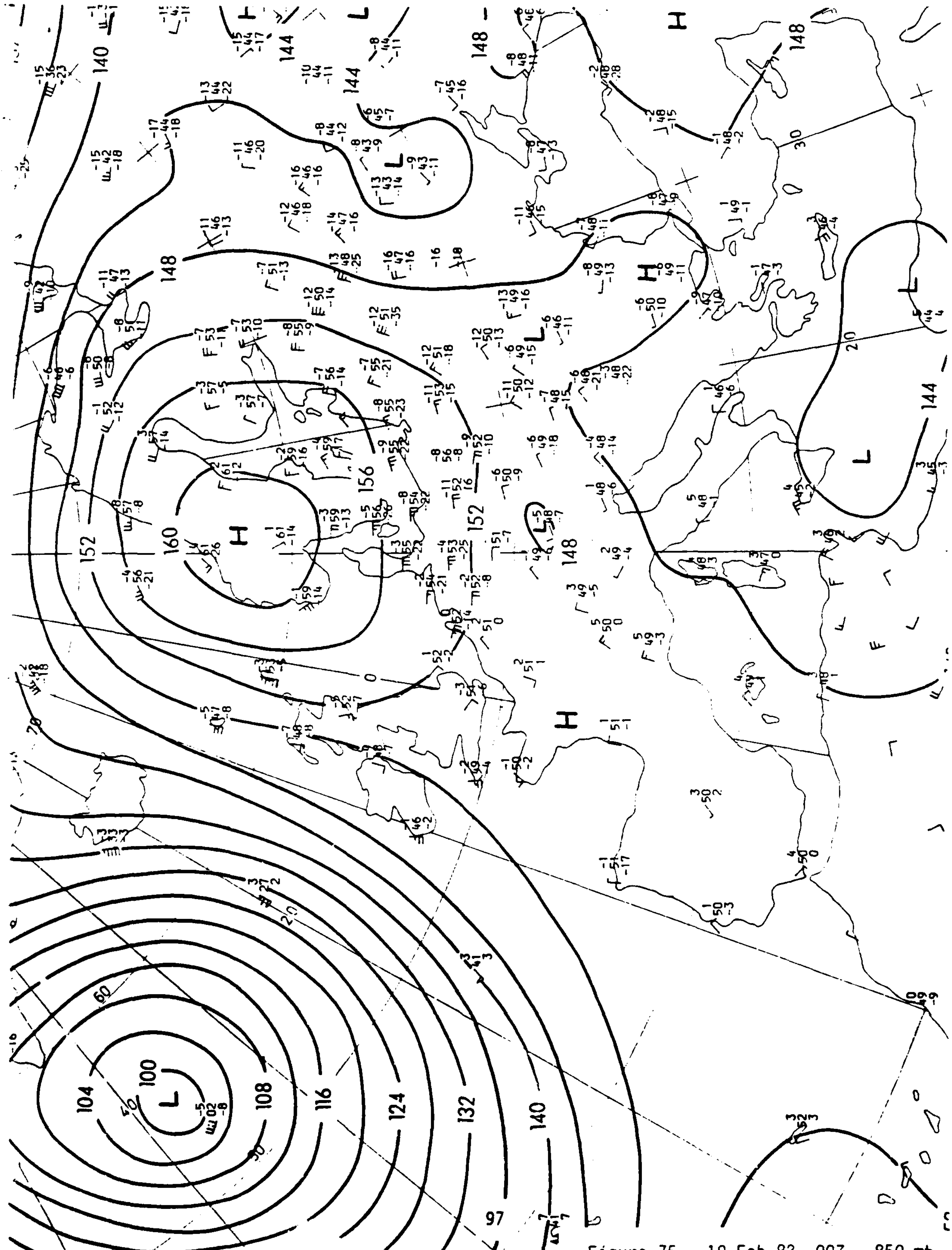

Figure 75. 19 Feb 82, 00Z - 850 mb

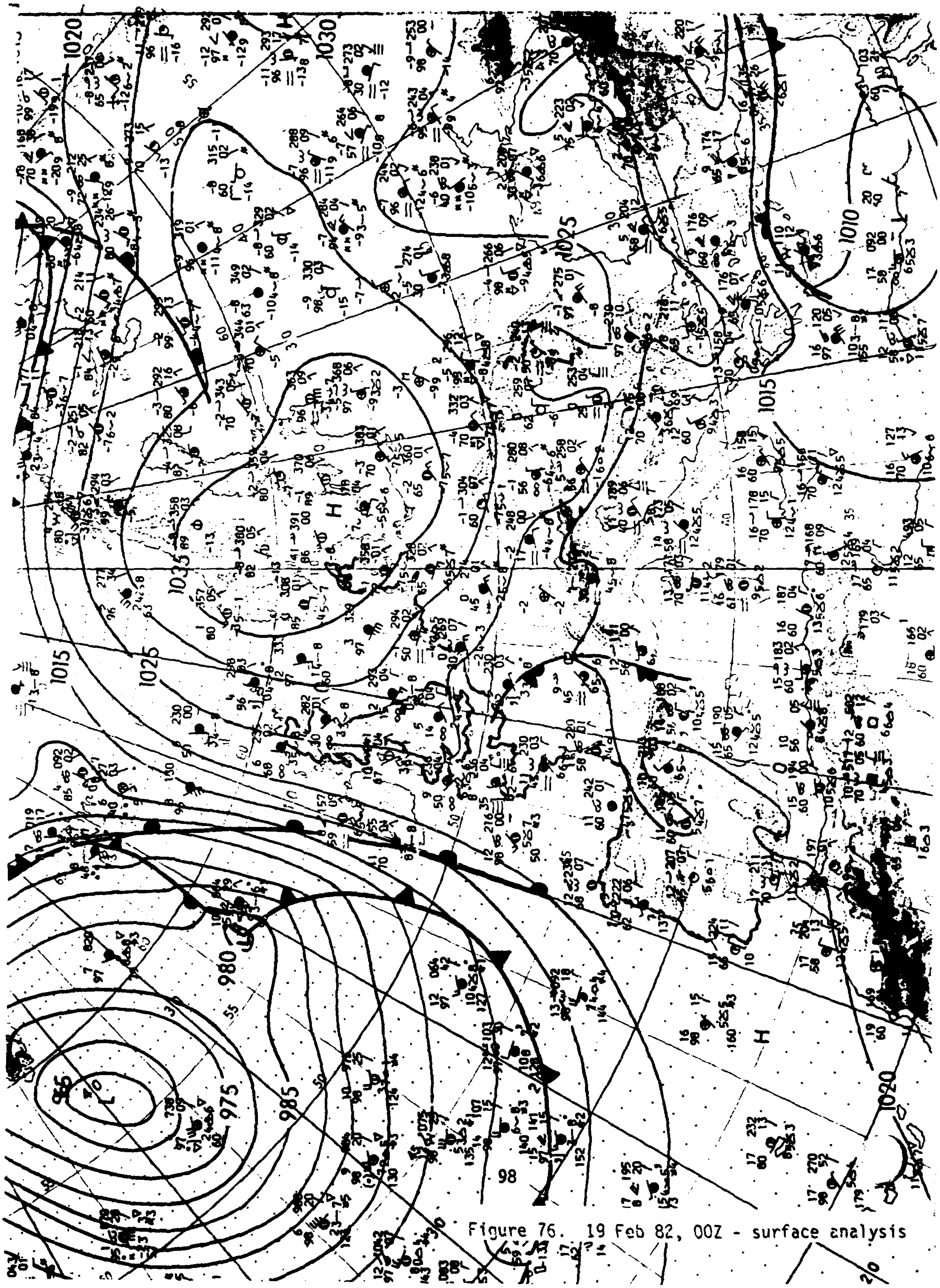

Figure 76. 19 Feb 82, 00Z - surface analysis

CASE 14. 21-23 December 1981. Another marginal case. On 21 Dec 81, 12Z (fig 77) a complex low pressure system extends in a trough from Jan Mayen southward over the U.K., France and into the western Mediterranean. A warm frontal occlusion stretches west-east over southern England and coastal Belgium then curves southward over the Ardennes Mountains into the Gulf of Lions. Then as a cold front, it extends into eastern Algeria. Temperatures are below freezing over Germany and it is snowing in the western and southwestern areas. After frontal passage, temperatures increased slightly and a few showers occurred as freezing precipitation. The 850 mb temperatures (fig 78) are up to -1°C, though 700 mb temperatures (fig 79) are -11°C, indicating unstable conditions aloft. Note that the 1000-500 mb thickness (fig 86) is between 5350 and 5320 gpm--a value which indicates snow rather than freezing precipitation. Also, low heights dominate the entire continent. The surface map on 22 Dec, 12Z (fig 81) has the front over northern Germany as a warm front because it is pushing the colder air at 850 mb into the North Sea. The trough is now located over France where isolated precipitation begins usually as rain with surface temperatures between 4° and 5°C. Since temperatures remain slightly below freezing over southwestern Germany, some freezing precipitation is occurring, but amounts are small. With the approach of the trough axis during the night, upper air temperatures drop again as the 850 mb (fig 82) and 700 mb (fig 84) analyses from 23 Dec 00Z show. With temperatures near -3°C at 850 mb and -15°C at 700 mb, and thickness values (fig 84) of 5280 gpm, freezing precipitation mixed with snow turns into snow. The radiosonde on 23 Dec 00Z from Stuttgart and Munich (fig 85) still show temperatures near 0°C at 920 mb reflecting the remnants of the more mild air that was advected from France the entire day. Lessons learned: Thickness values lower than 5330 gpm can produce freezing precipitation if the surface temperatures are below 0°C. Under unstable conditions, like over France, surface temperatures can be above freezing and precipitation may occur as rain or rain mixed with snow. Thickness alone doesn't work, you must crosscheck with upper level temperatures, not necessarily the mandatory levels.

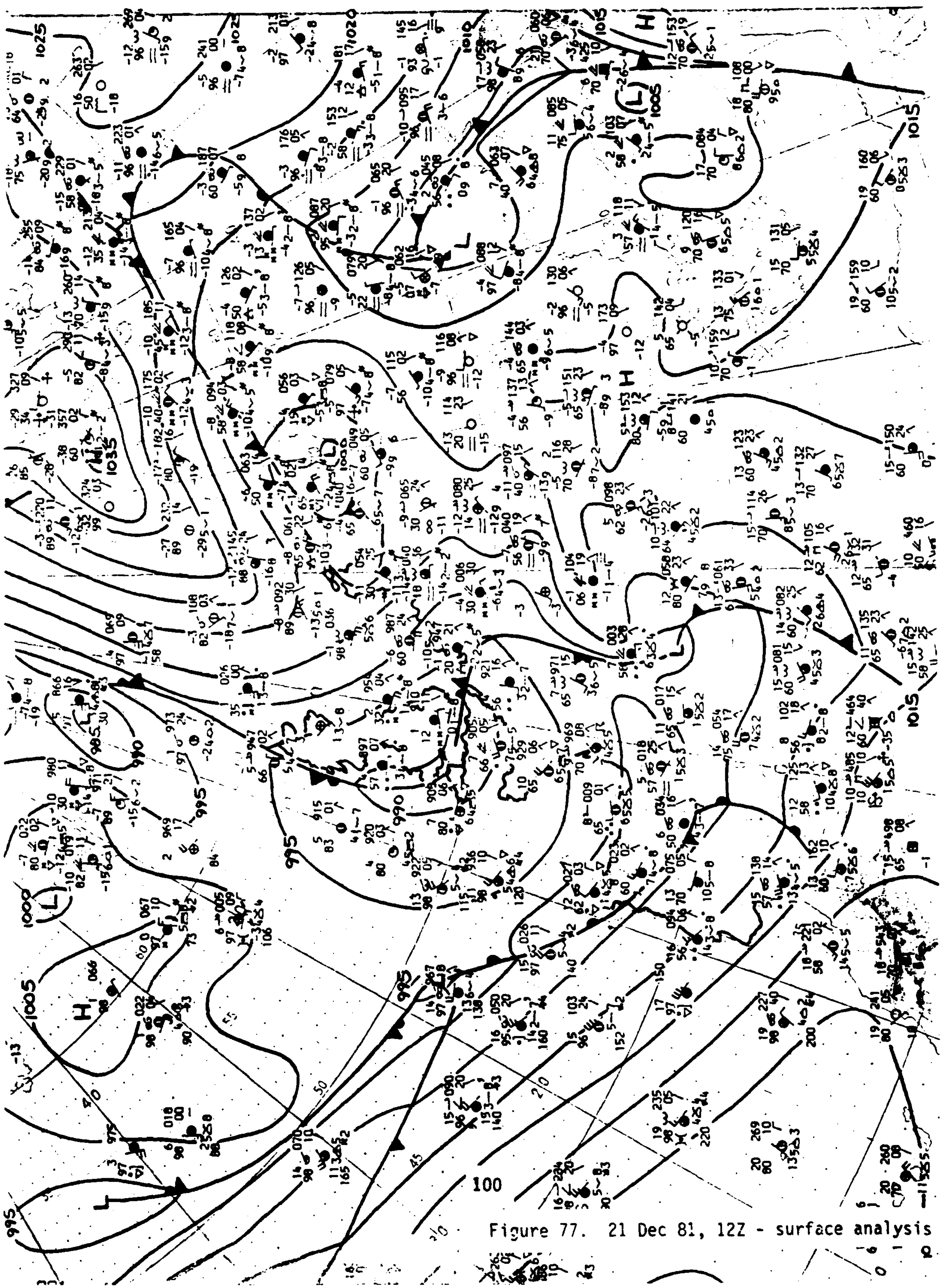

Figure 77. 21 Dec 81, 12Z - surface analysis

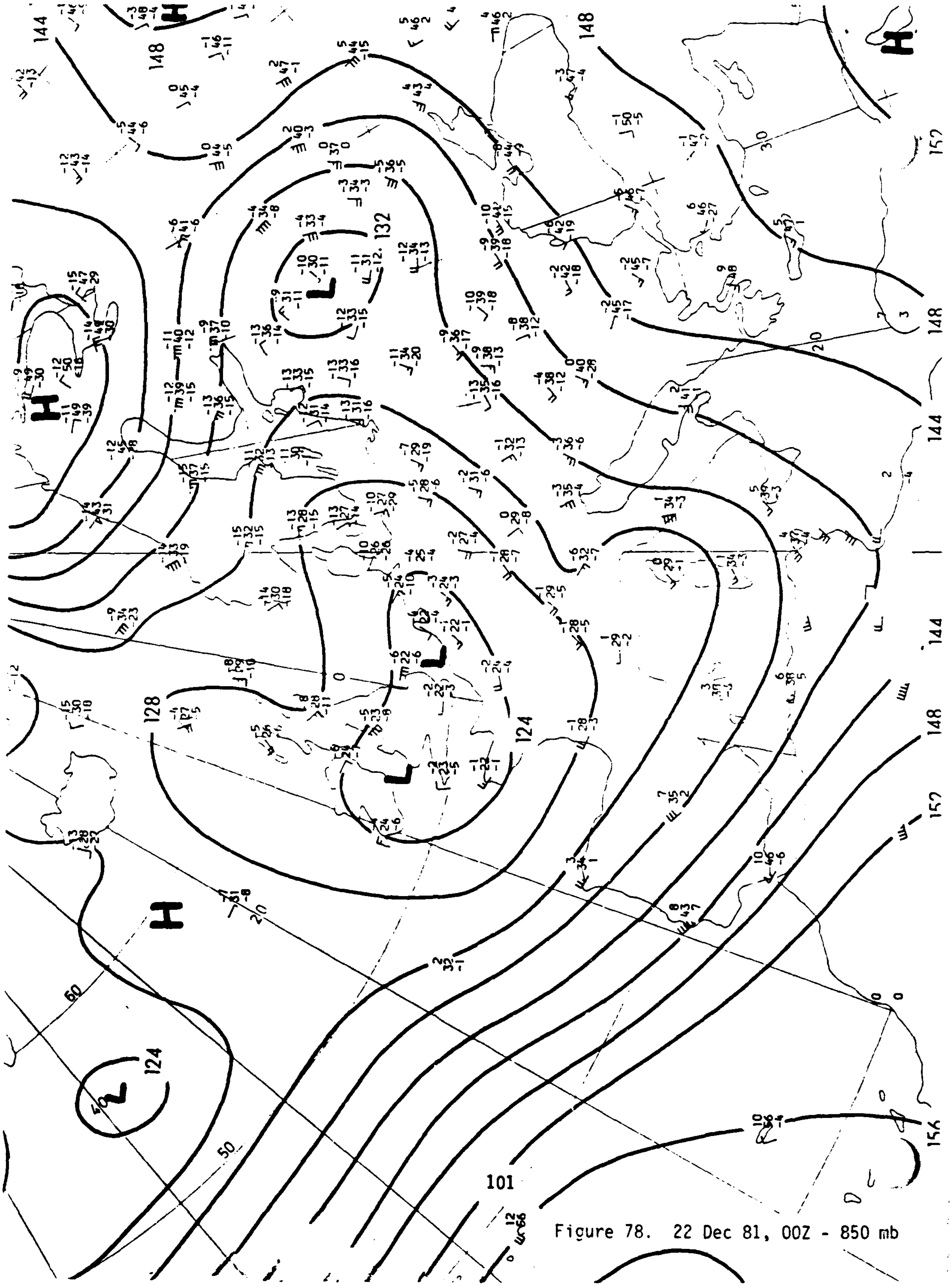

Figure 78. 22 Dec 81, 00Z - 850 mb

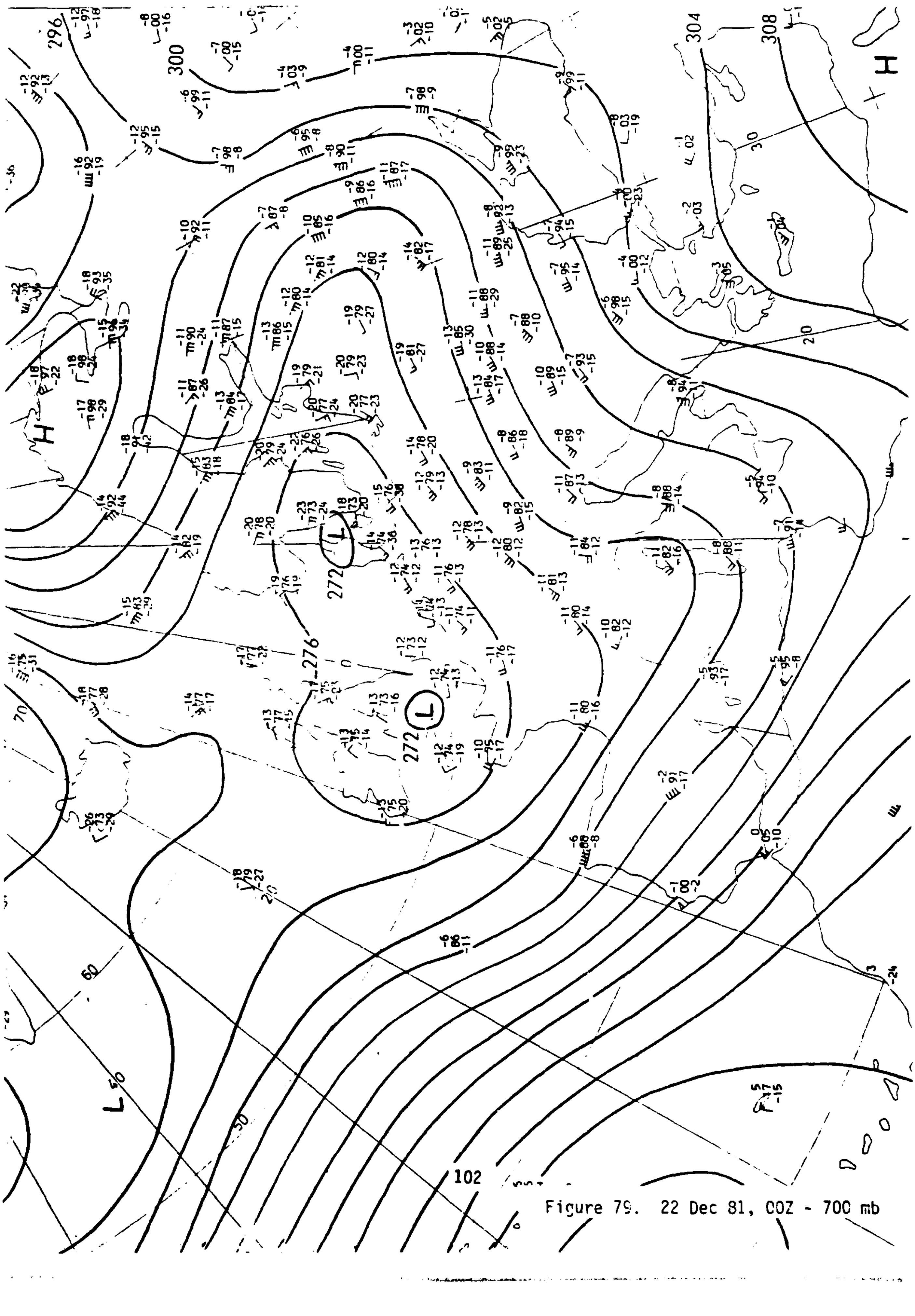

Figure 79. 22 Dec 81, 00Z - 700 mb

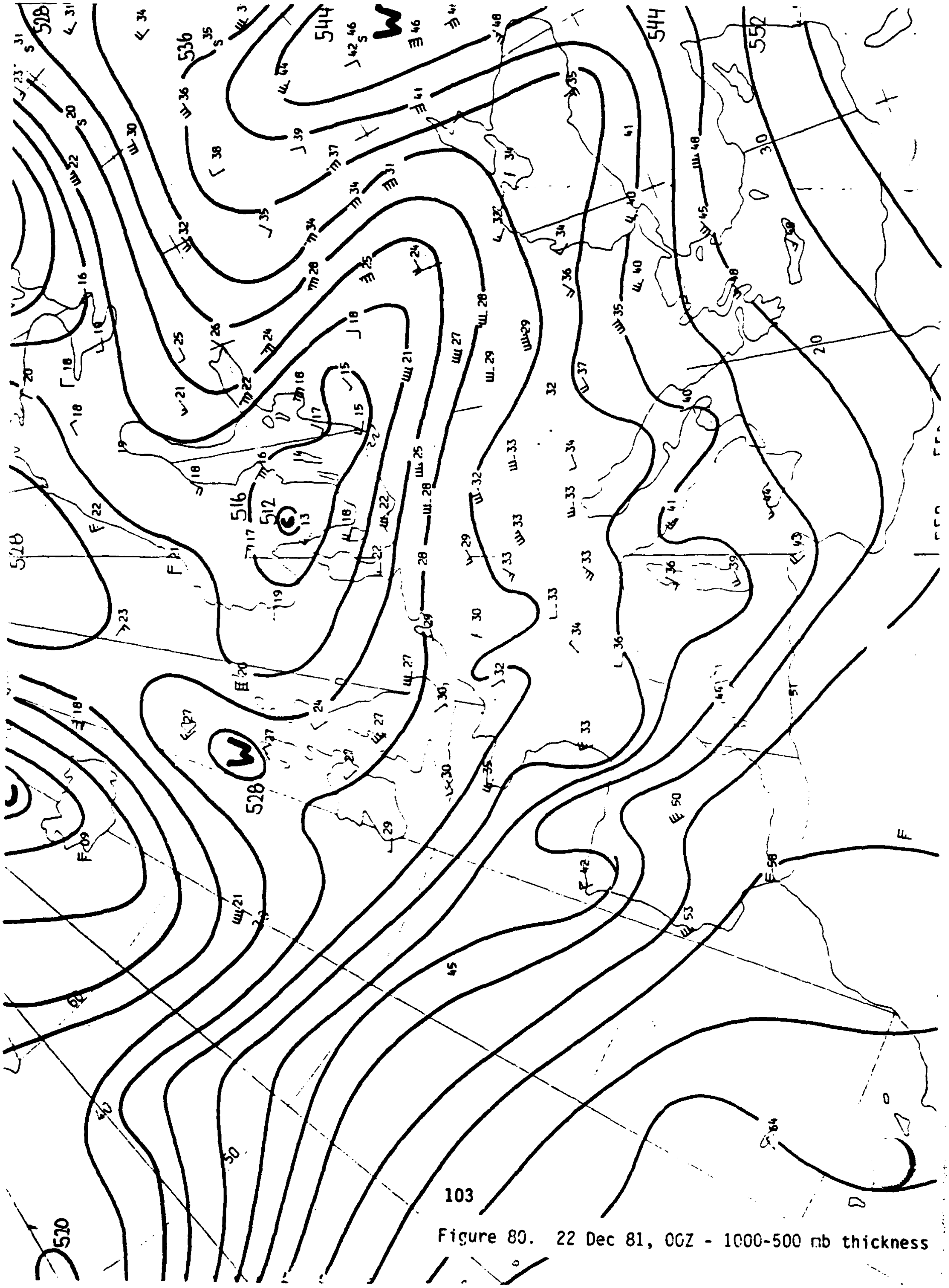

Figure 80. 22 Dec 81, 00Z - 1000-500 mb thickness

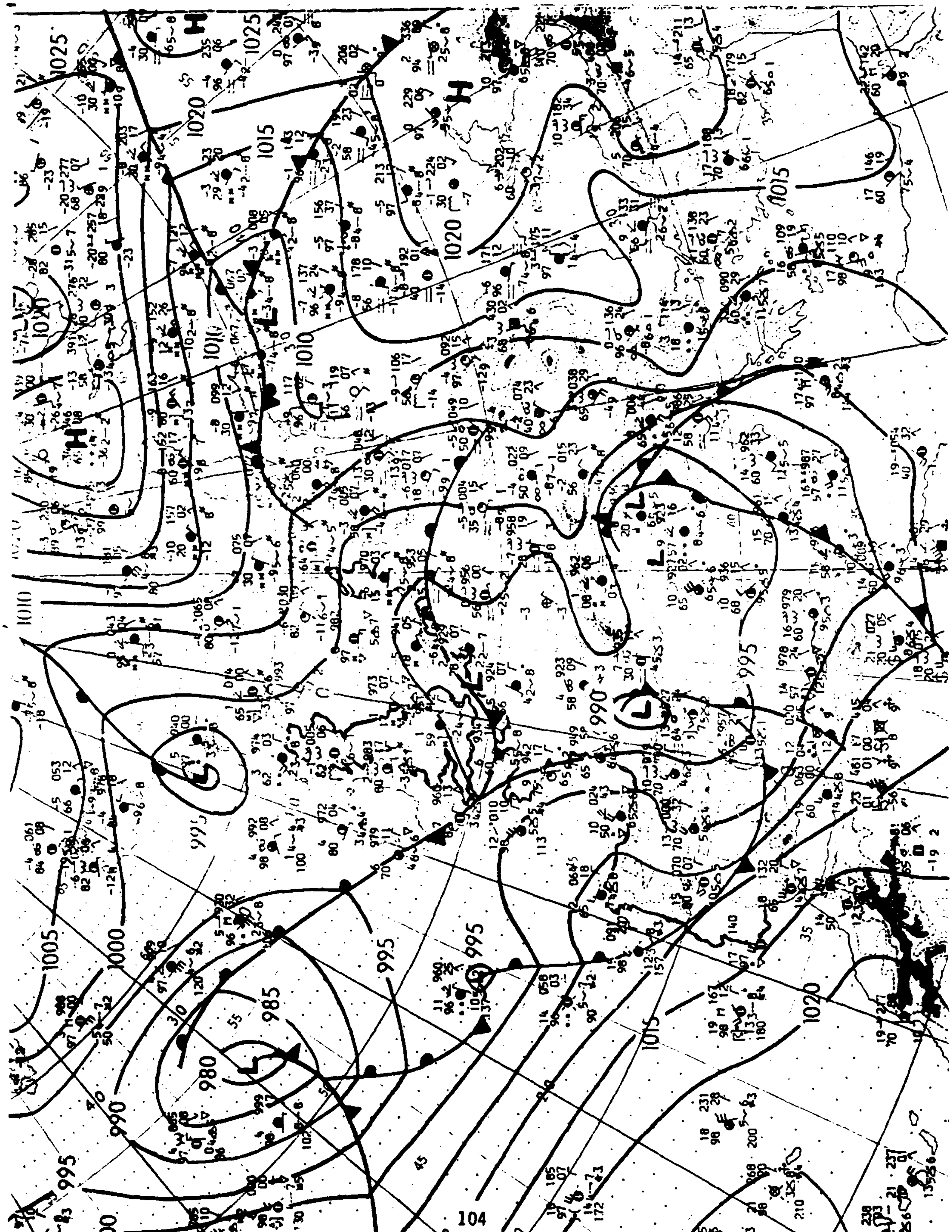

Figure 81. 22 Dec 81, 12Z - surface analysis

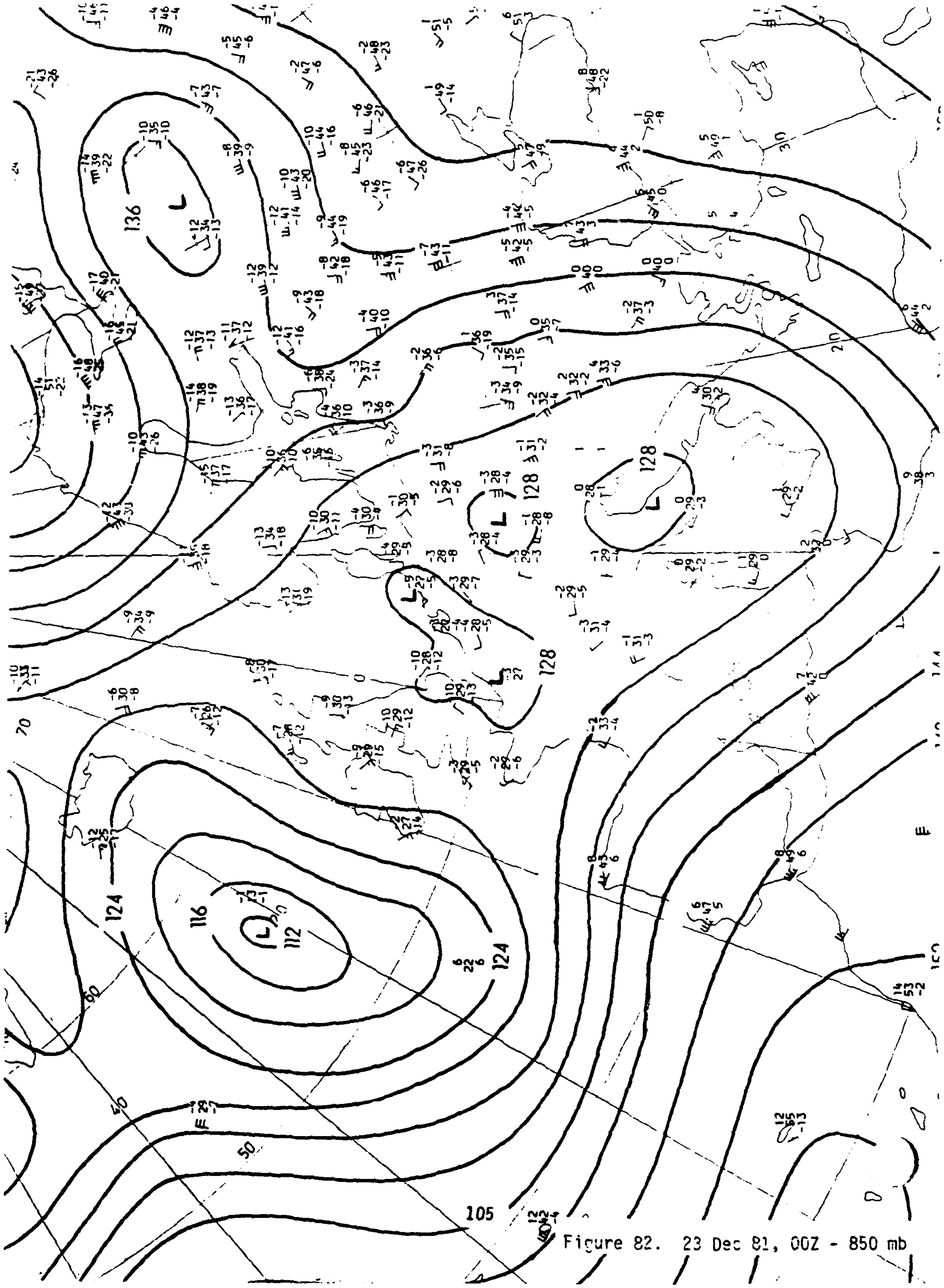

Figure 82. 23 Dec 81, 00Z - 850 mb

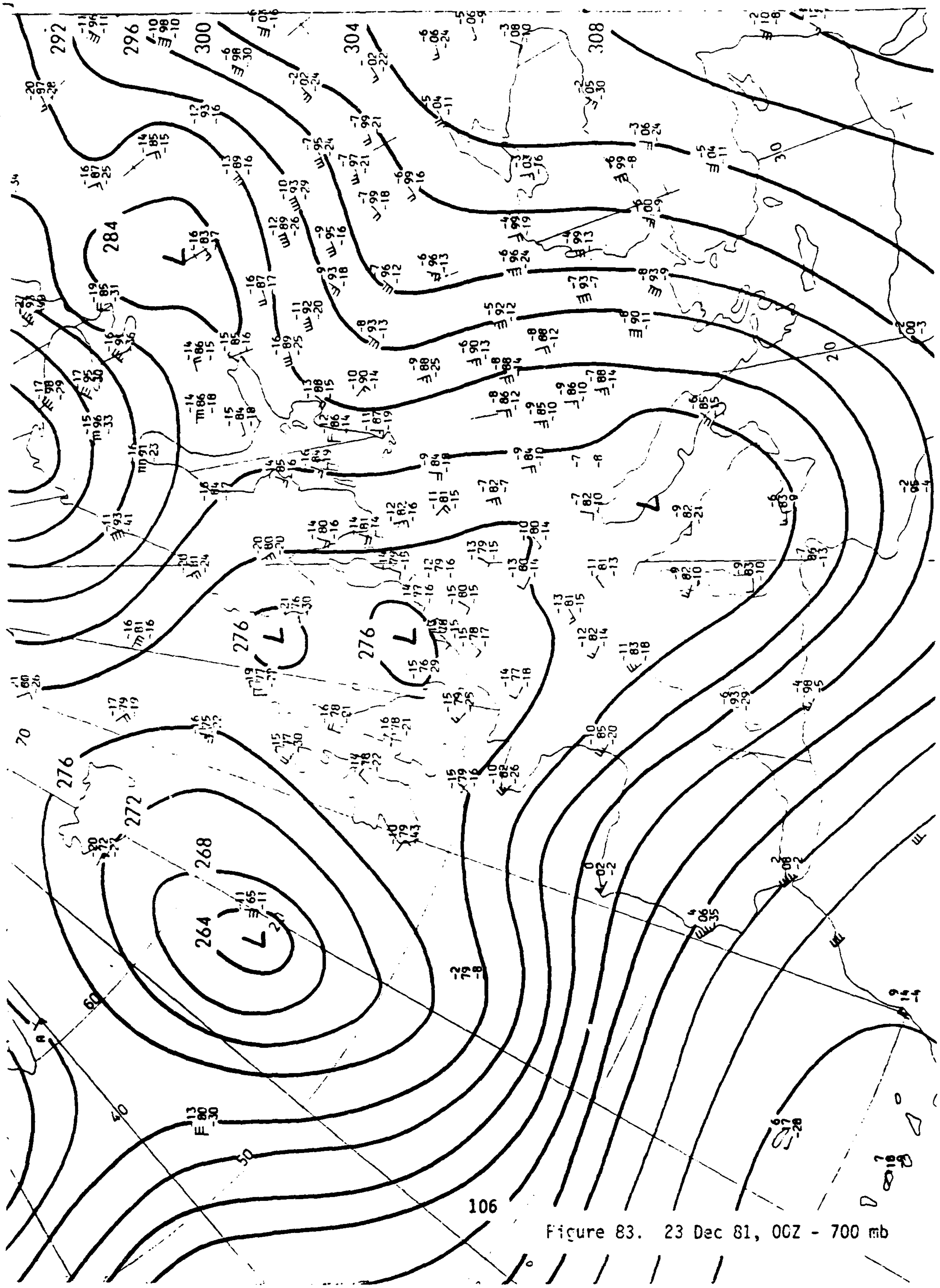

Figure 83. 23 Dec 81, 00Z - 700 mb

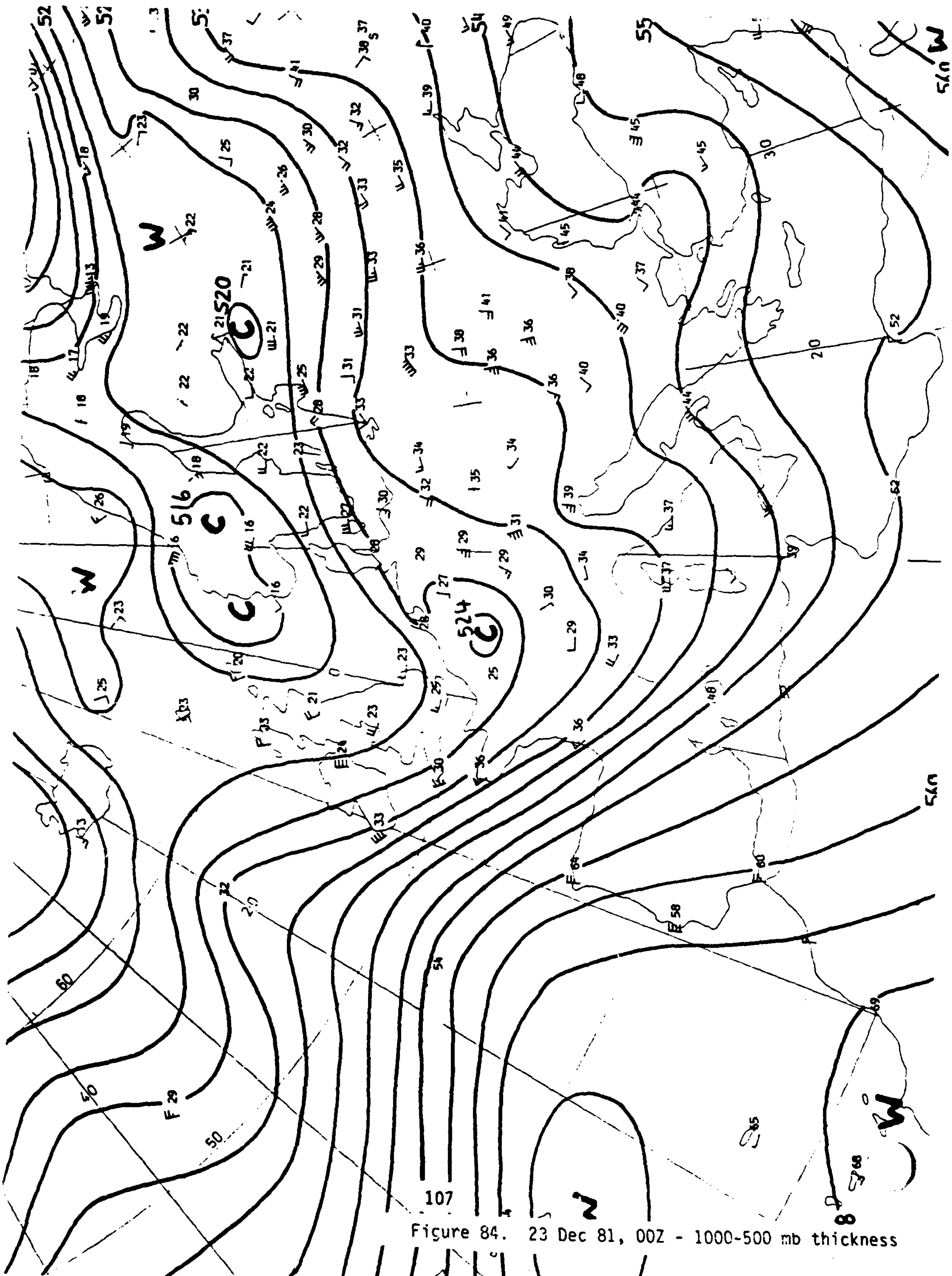

Figure 84. 23 Dec 81, 00Z - 1000-500 mb thickness

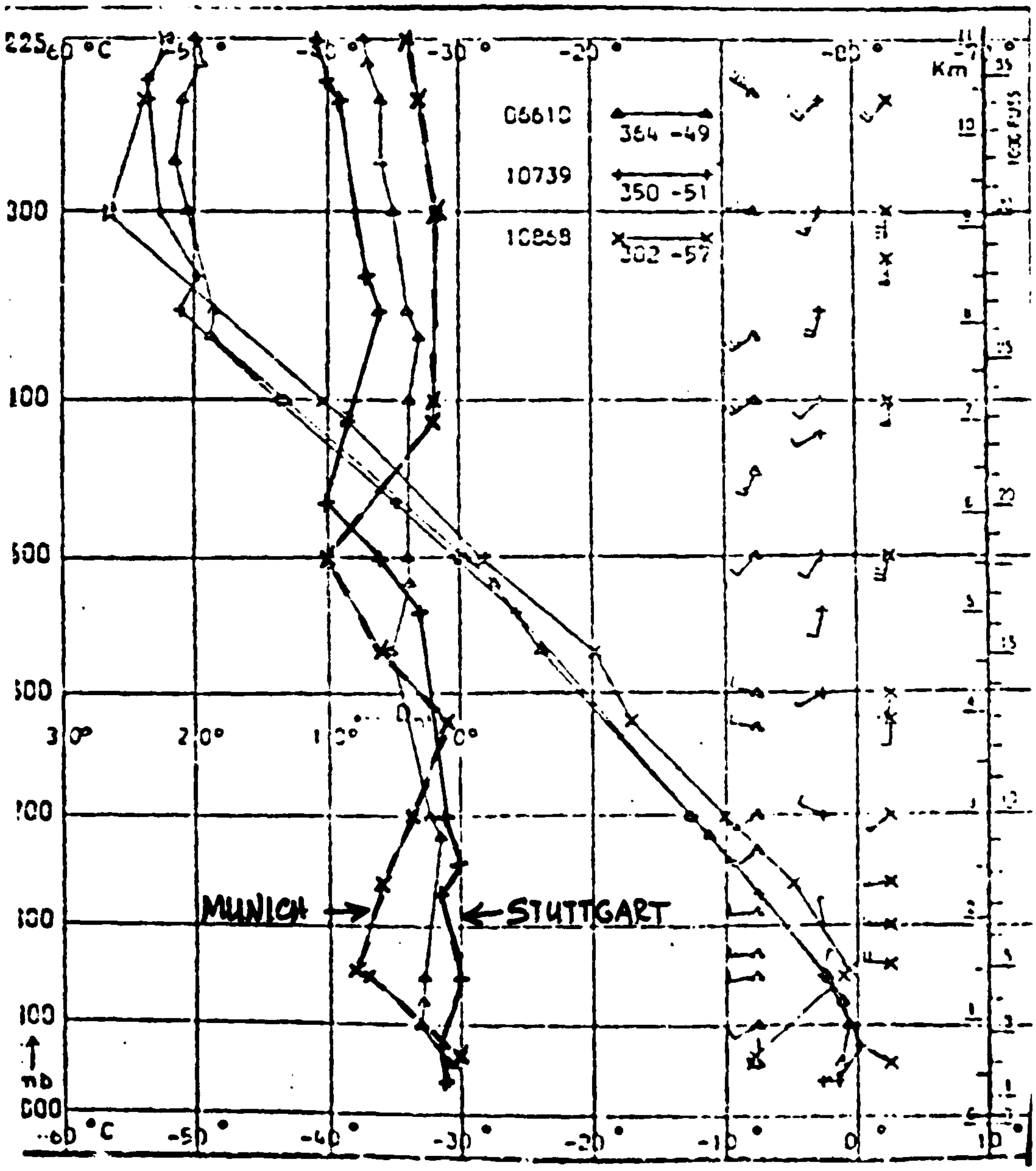

Figure 85. 23 Dec 81, 00Z - Stuttgart/Munich Radiosonde

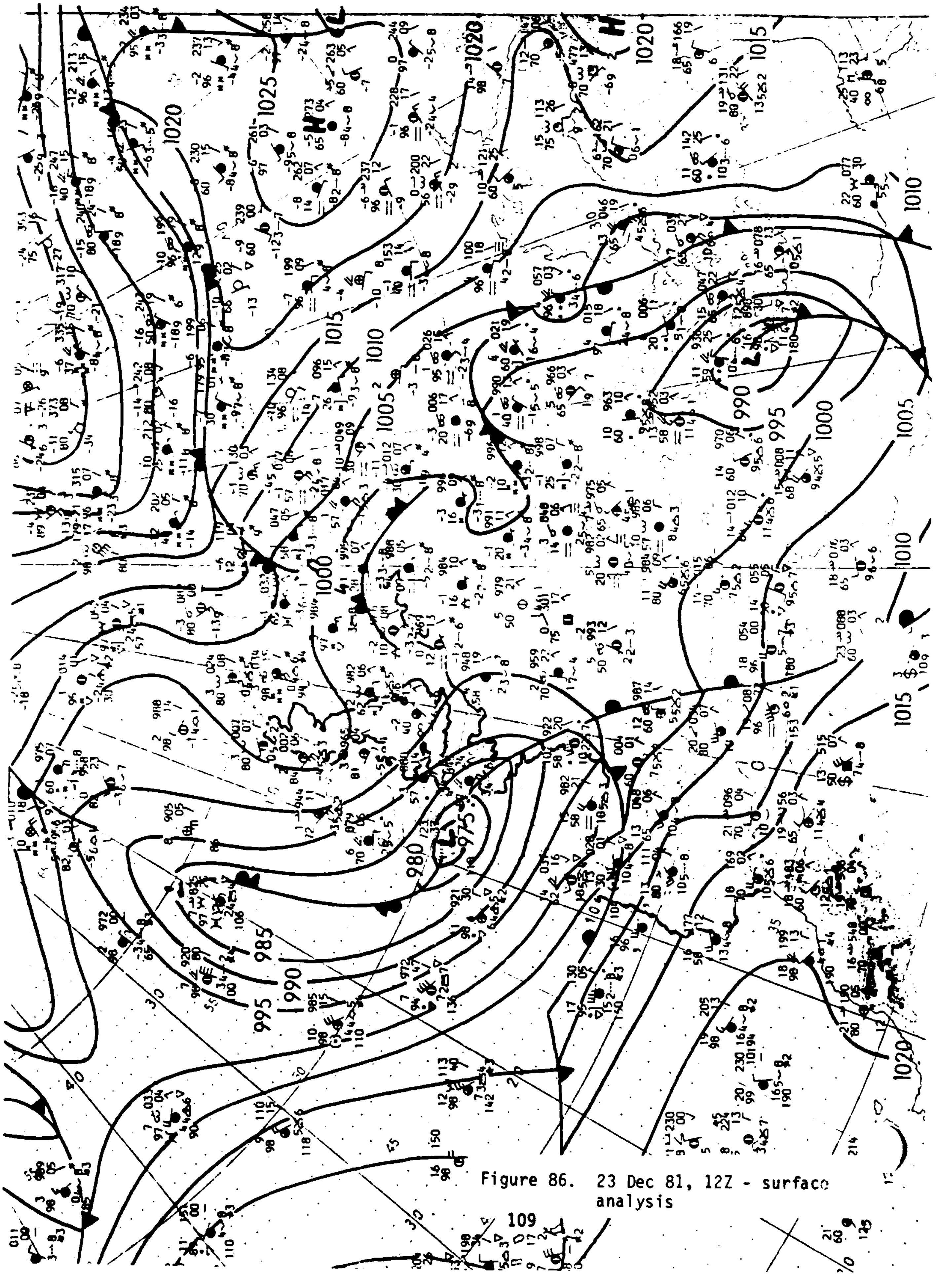

Figure 86. 23 Dec 81, 12Z - surface analysis

CASE 15. 19-23 January 1979. Freezing precipitation in the Netherlands. Northwest Germany, the Netherlands, and Belgium are areas where freezing precipitation is rare. Because it is rare, good working tools are not readily available. The following case is a kind of "typical occurrence" of freezing precipitation in the northwest. The surface analysis of 19 Jan 79 (fig 87) shows low pressure over the Bay of Biscaye and a warm front extending southeastward to the Mediterranean and into the Gulf of Sidra. The cold front is southwest of the Pyrenees and stretches southward over the Atlas mountains into the Sahara desert. The entire configuration gives the impression of Saharan air being advected into France. The 300 mb chart from 20 Jan 00Z (fig 88) shows this is not the case. Instead, the bulge over eastern France indicates Mediterranean air is being advected. This air is warm enough to produce rain or freezing rain. In such cases, a rain/freezing rain forecast can be made using trajectory data. The 850 mb of 20 Jan 00Z (figs 89 and 90) support this idea. The warm air advection over France is clearly depicted by the 1000-500 mb thickness chart (fig 91). As the front moves northeastward it is producing freezing precipitation over western Germany and the Netherlands (fig 92). As the front weakens, it cannot cross the first major mountain range: the Ardennes-Eifel-Saarpfalz-Vosges. The 850 mb (fig 93) and 700 mb map (fig 94) on 21 Jan 00Z show no significant change. It is still too warm for snow over the continent. Note the temperature drop, -5°C at 850 mb, and -13°C at 700 mb, over the U.K. The disintegration of the front over western Germany is seen on the analysis from 21 Jan 12Z (fig 95). Note the Netherlands are still under easterly flow and that northern France, the English Channel, and large parts of England are covered by dense mixing fog (despite the instability in upper levels!). The reason which cannot be depicted from the maps, is snow melt! The configuration of the dissipating occlusion is causing a westward push of cold air from northern Germany with occasional freezing precipitation and ice pellets over western Germany and the Netherlands. The 850 mb analysis on 22 Jan 00Z (fig 96) still shows warm air advection over France but a northerly to easterly flow over the Netherlands and England. Temperatures range from -1°C at De Bilt to -3°C at Emden (German North Sea coast) and Hemsby (near the Wash). It looks like the freezing precipitation is over. The 1000-500 mb thicknesses (fig 97) of 5350 to 5320 appear to support this. At 12Z, 22 Jan (fig 98), the front has retreated southwestward and snow begins falling in northern Germany, whereas the sky is clearing along the North Sea coast. However, the low west of the English Channel is now forced to move east-northeast again. The 850 mb (fig 99) and 700 mb (fig 100) temperatures on 23 Jan 00Z indicate rain or freezing rain. Winds at 850 mb are weak (C-10 knots) and cold air advection from Iceland is pushing the low a little further south, a path which results in a classic configuration of freezing rain/snow/rain, very similiar to systems which move over the Great Lakes. The 23 Jan 12Z surface analysis (fig 102), shows freezing precipitation at Hamburg and snow over the southern North Sea and the U.K. (London). In Germany, the movement of the low and the associated strong cyclonic flow aloft replaces some of the cold air with warmer air; therefore, the precipitation is falling as rain. This ends a lengthy period of warm air overrunning very cold continental air. This 4 day sequence is still indicated in the Soesterberg RUSSWO--certainly a bias toward freezing precipitation. The primary problem over the Netherlands is not forecasting the 850 mb temperature, it's forecasting of the surface temperature. It would have worked with this case. Knowing this, the Dutch have developed a method to forecast freezing precipitation (see Appendix A).

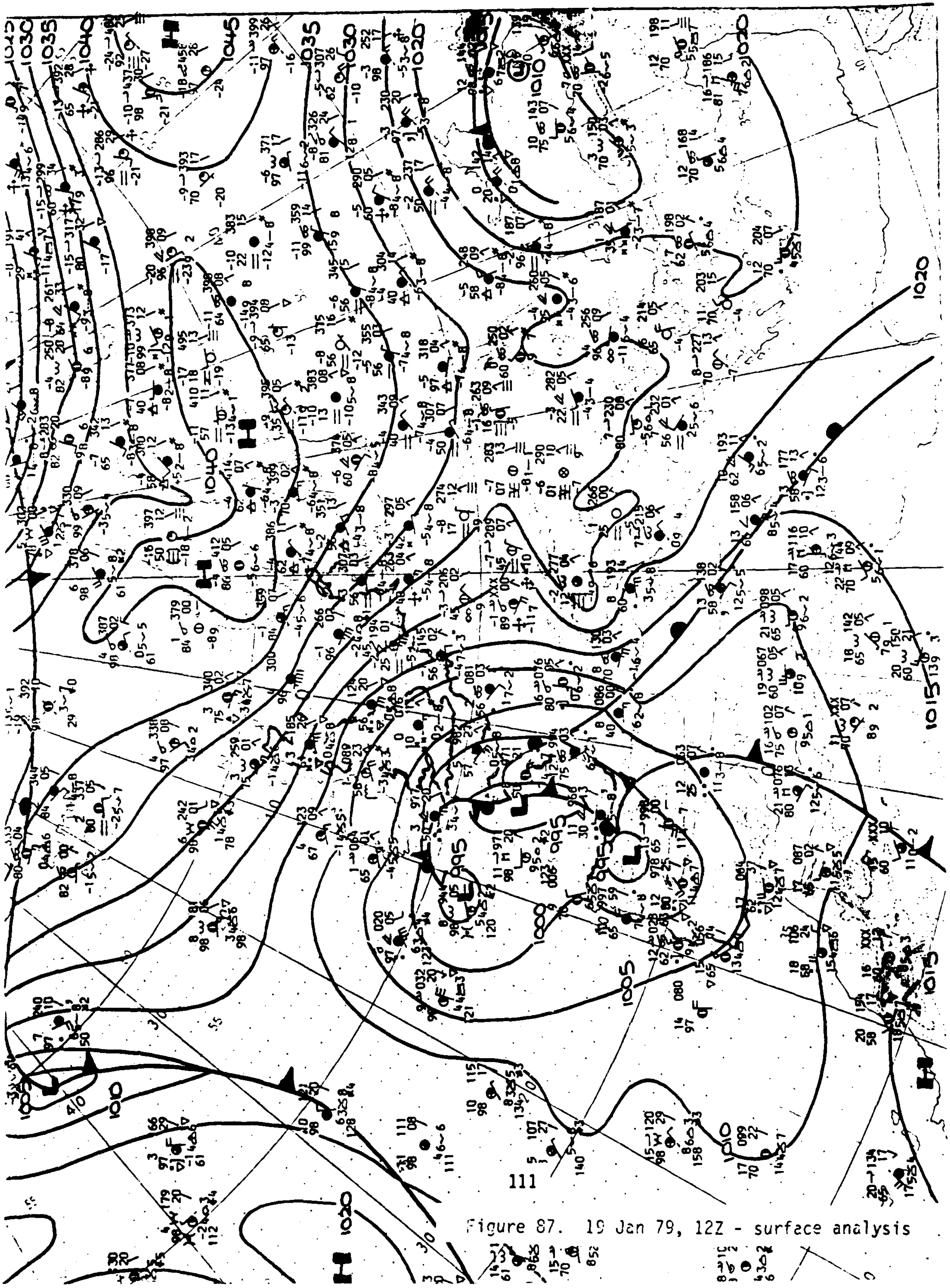

Figure 87. 19 Jan 79, 12Z - surface analysis

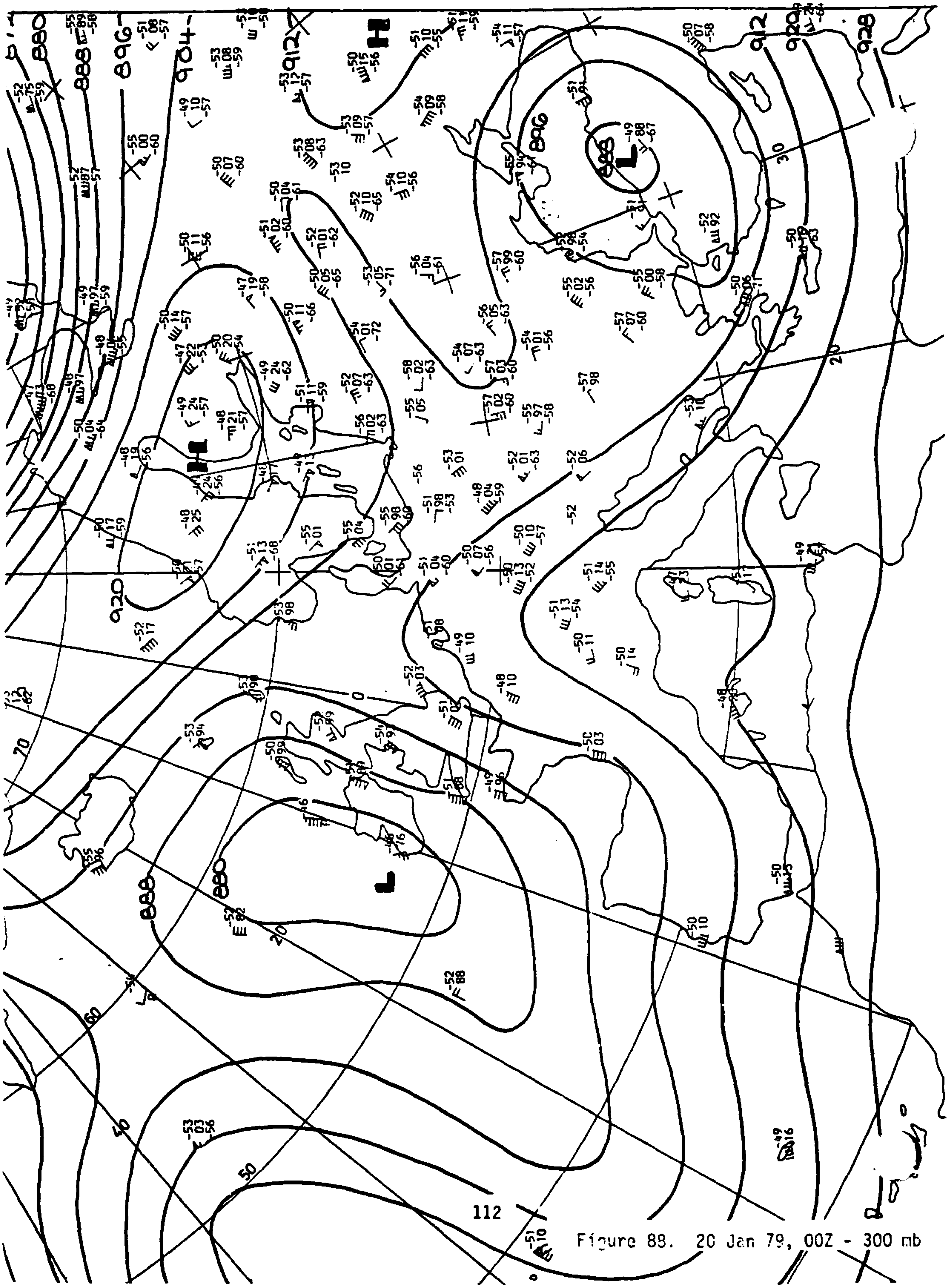

Figure 88. 20 Jan 79, 00Z - 300 mb

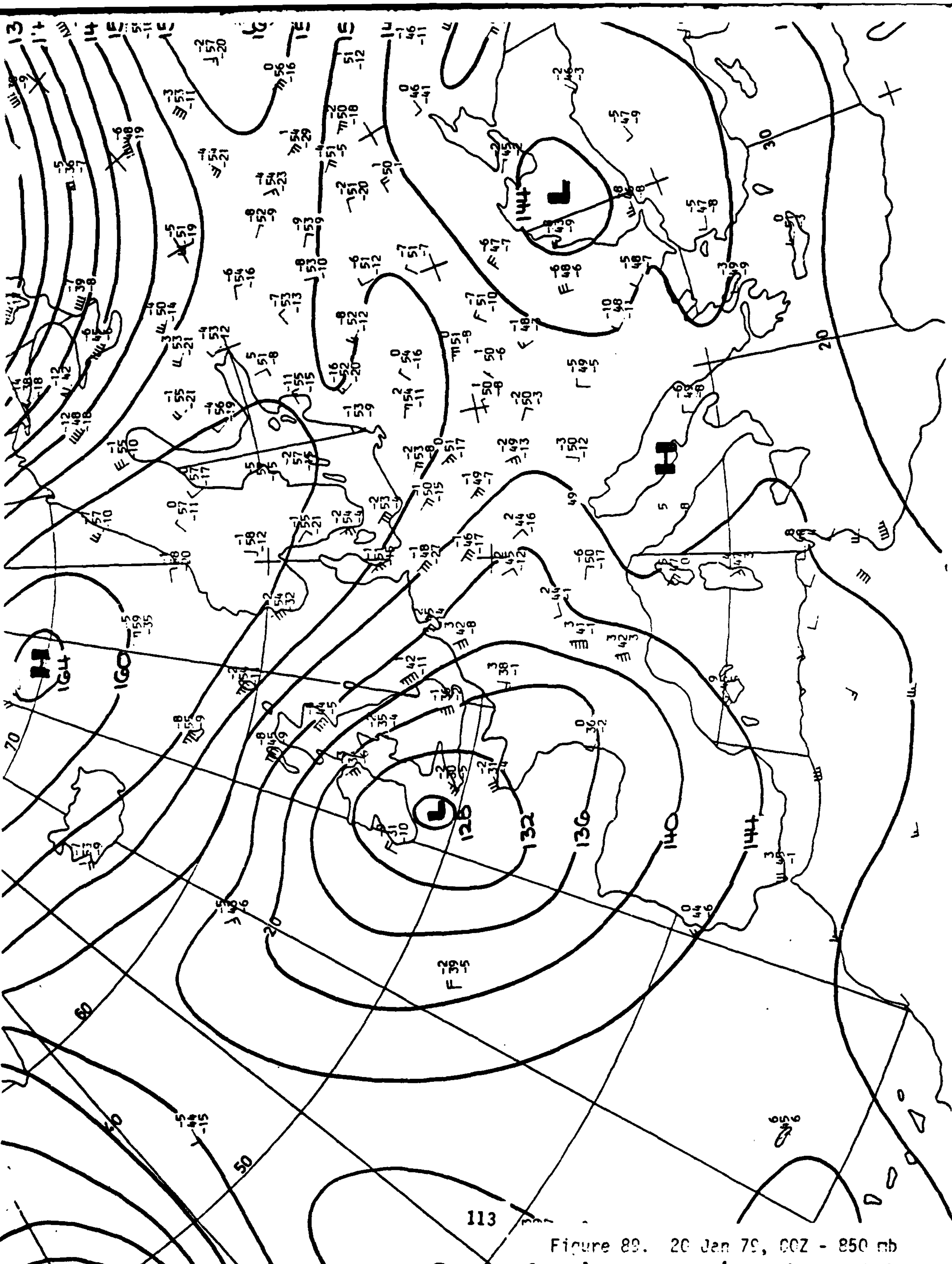

Figure 89. 20 Jan 79, 00Z - 850 mb

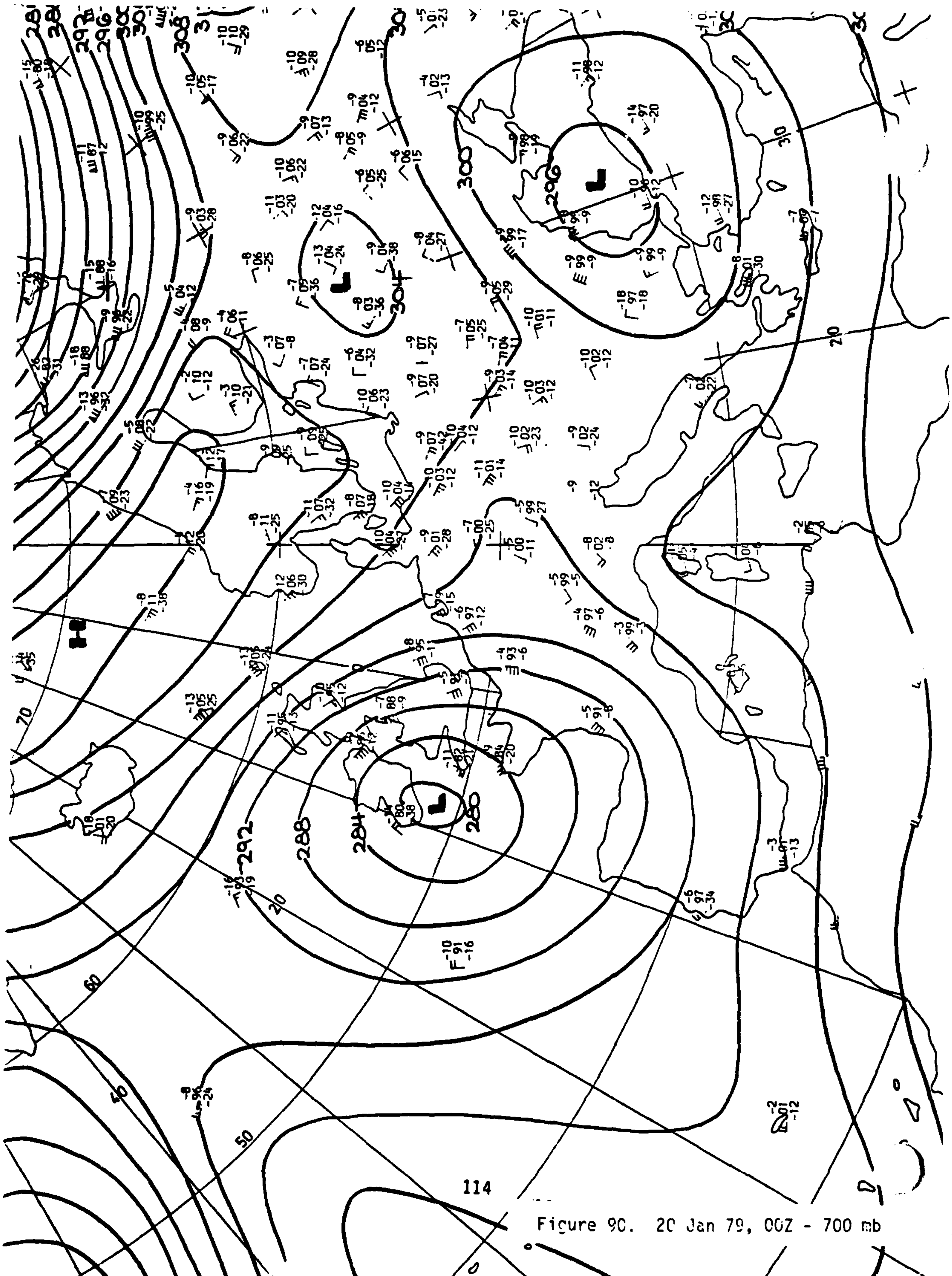

Figure 90. 20 Jan 79, 00Z - 700 mb

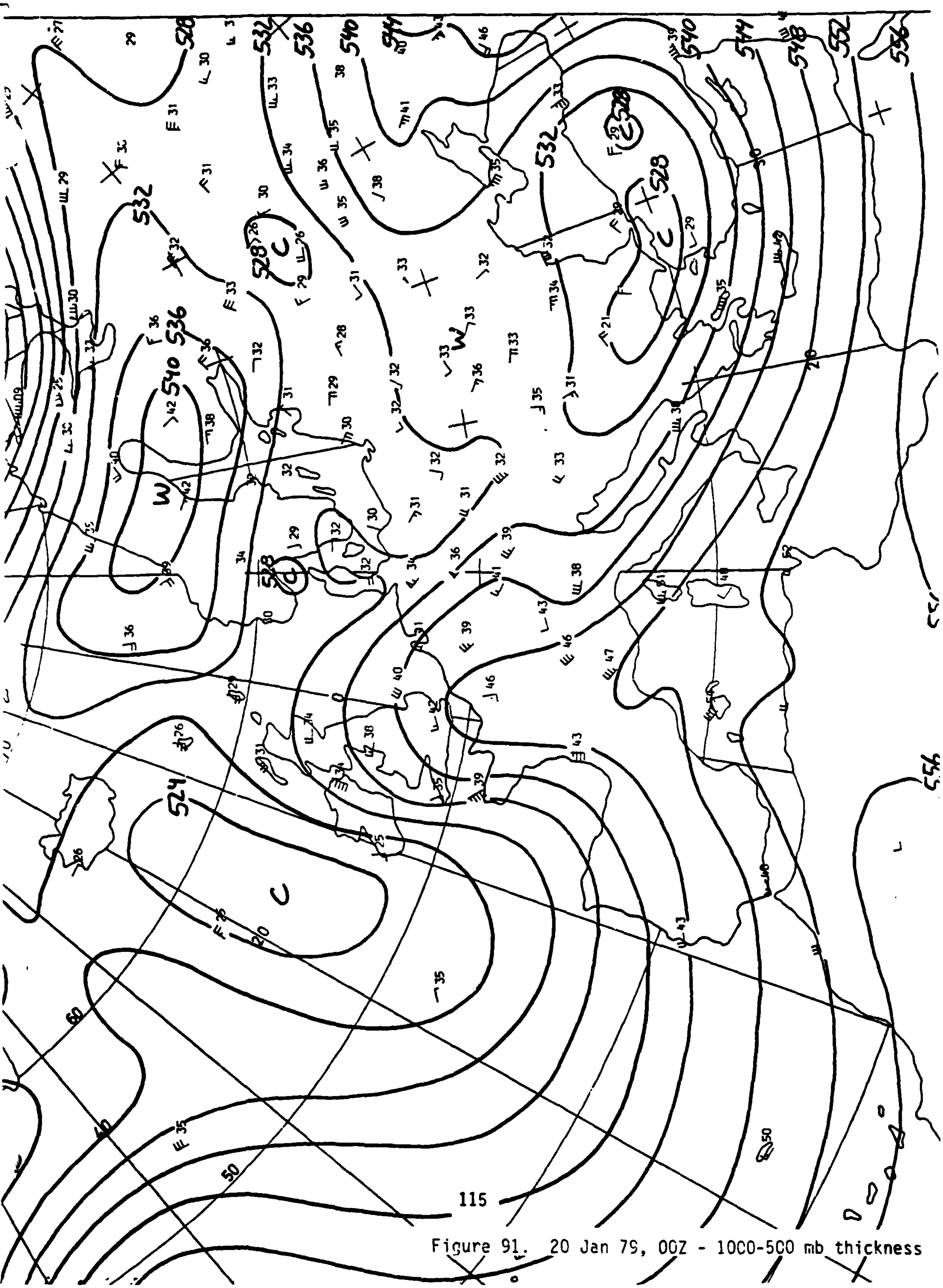

Figure 91. 20 Jan 79, 00Z - 1000-500 mb thickness

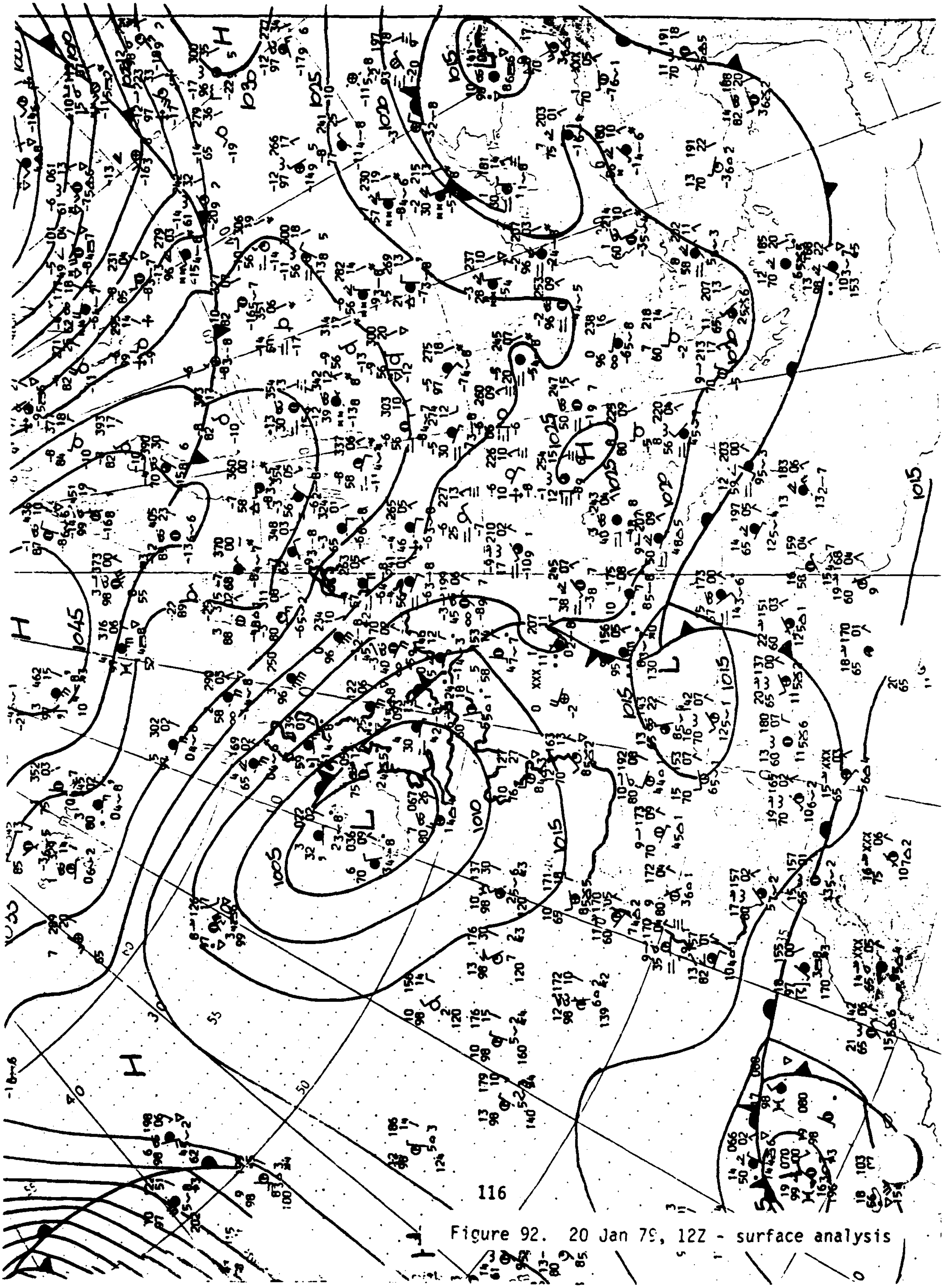

Figure 92. 20 Jan 79, 12Z - surface analysis

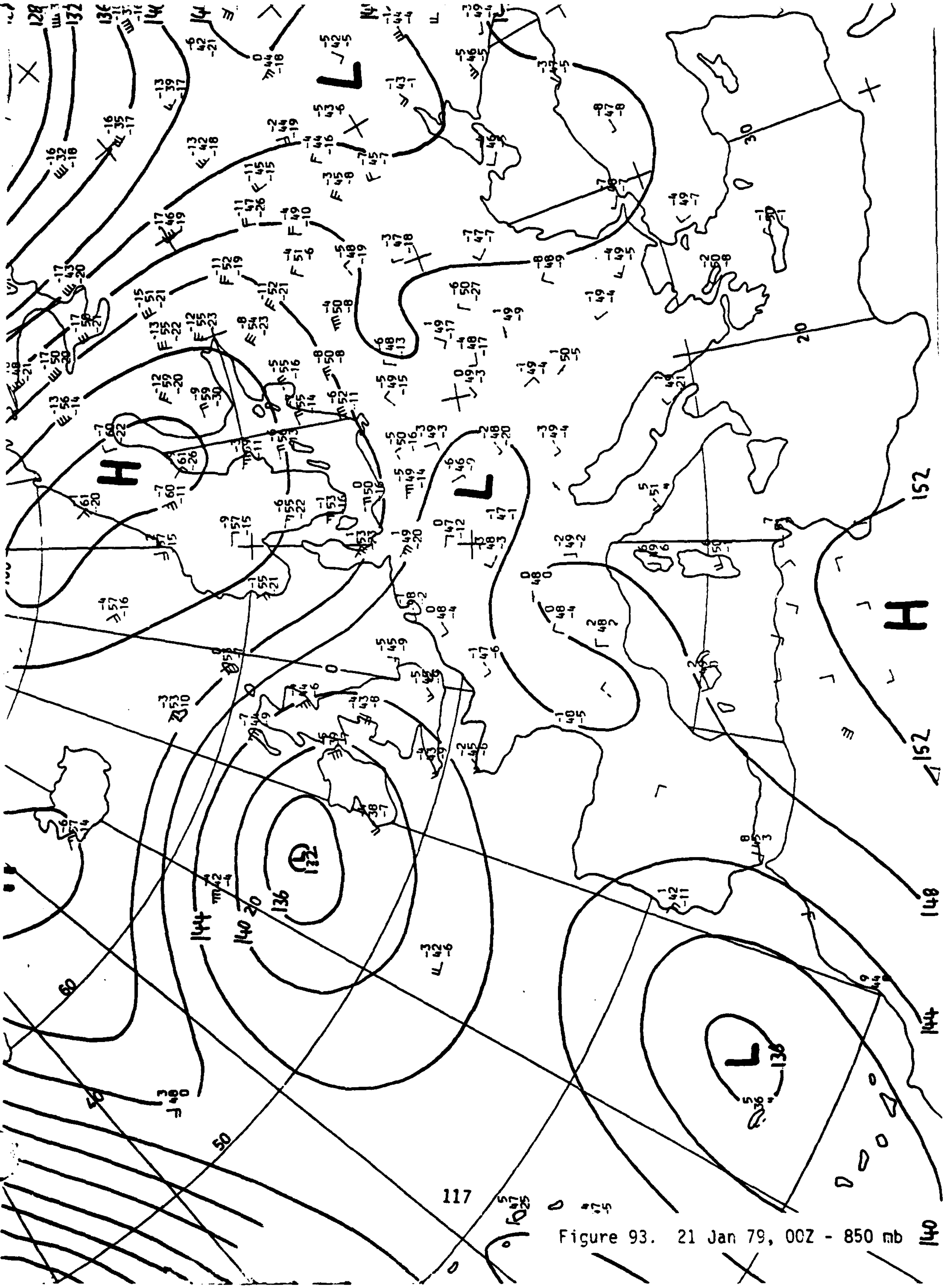

Figure 93. 21 Jan 79, 00Z - 850 mb

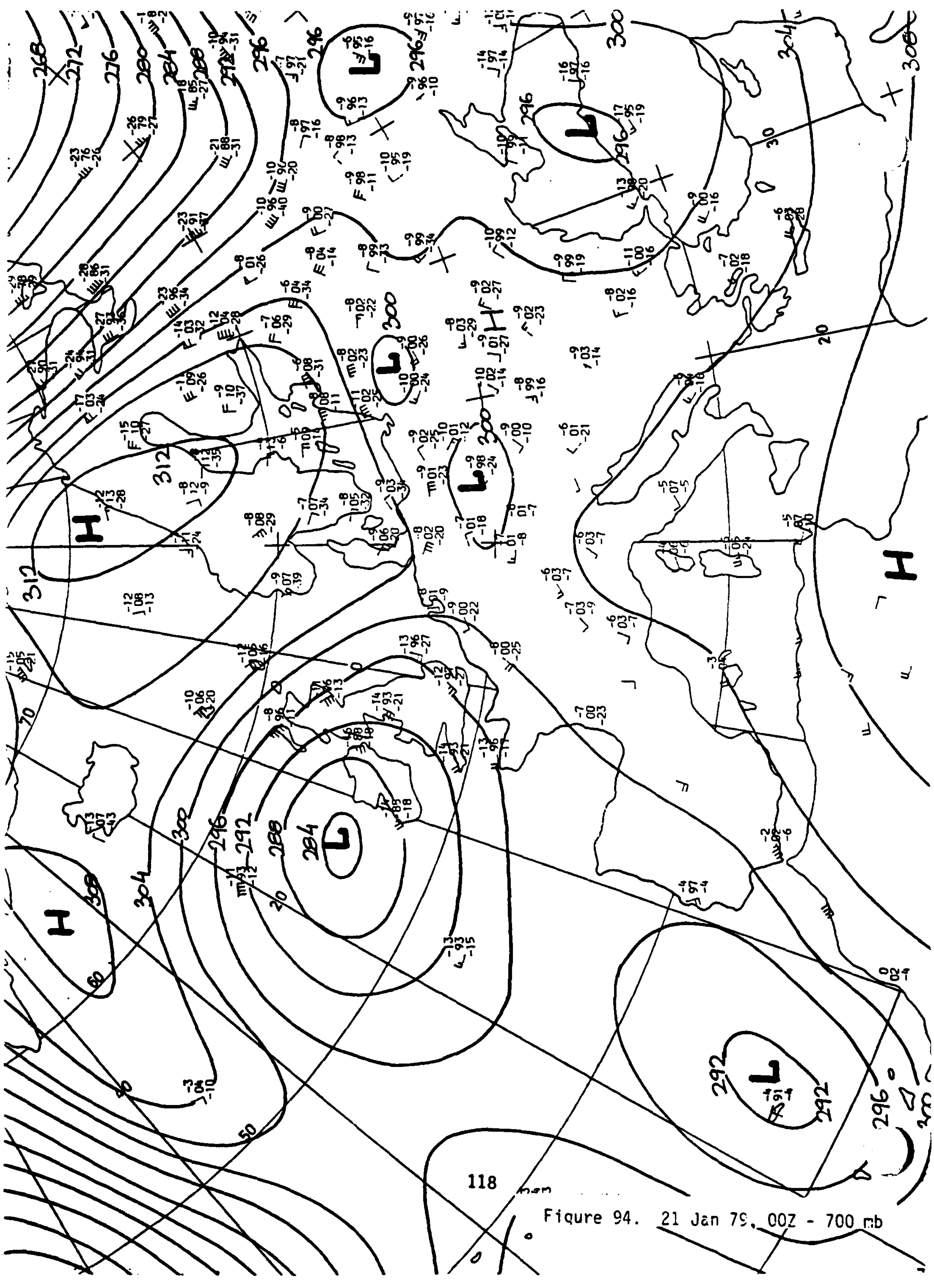

Figure 94. 21 Jan 79, 00Z - 700 mb

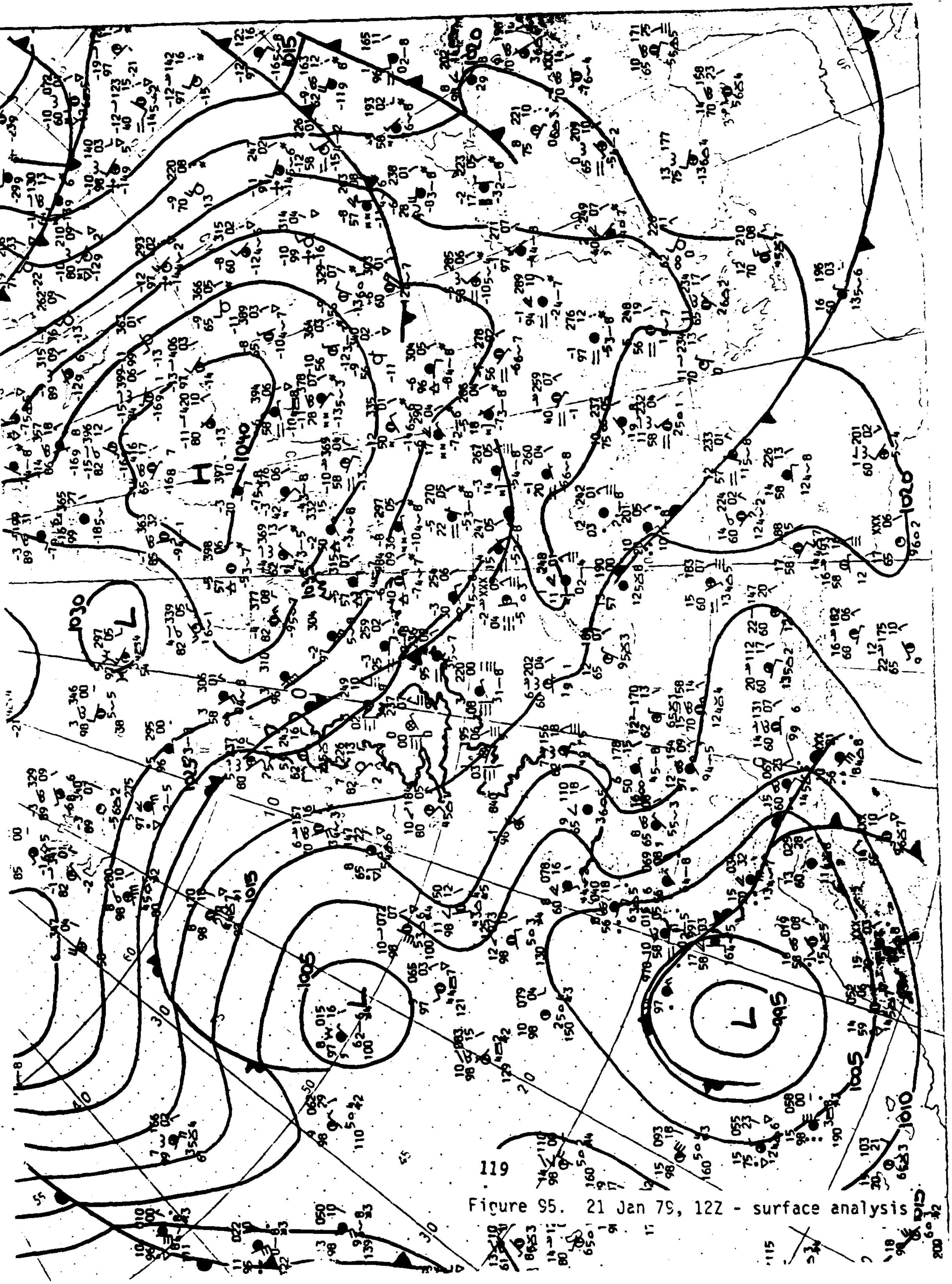

Figure 95. 21 Jan 79, 12Z - surface analysis

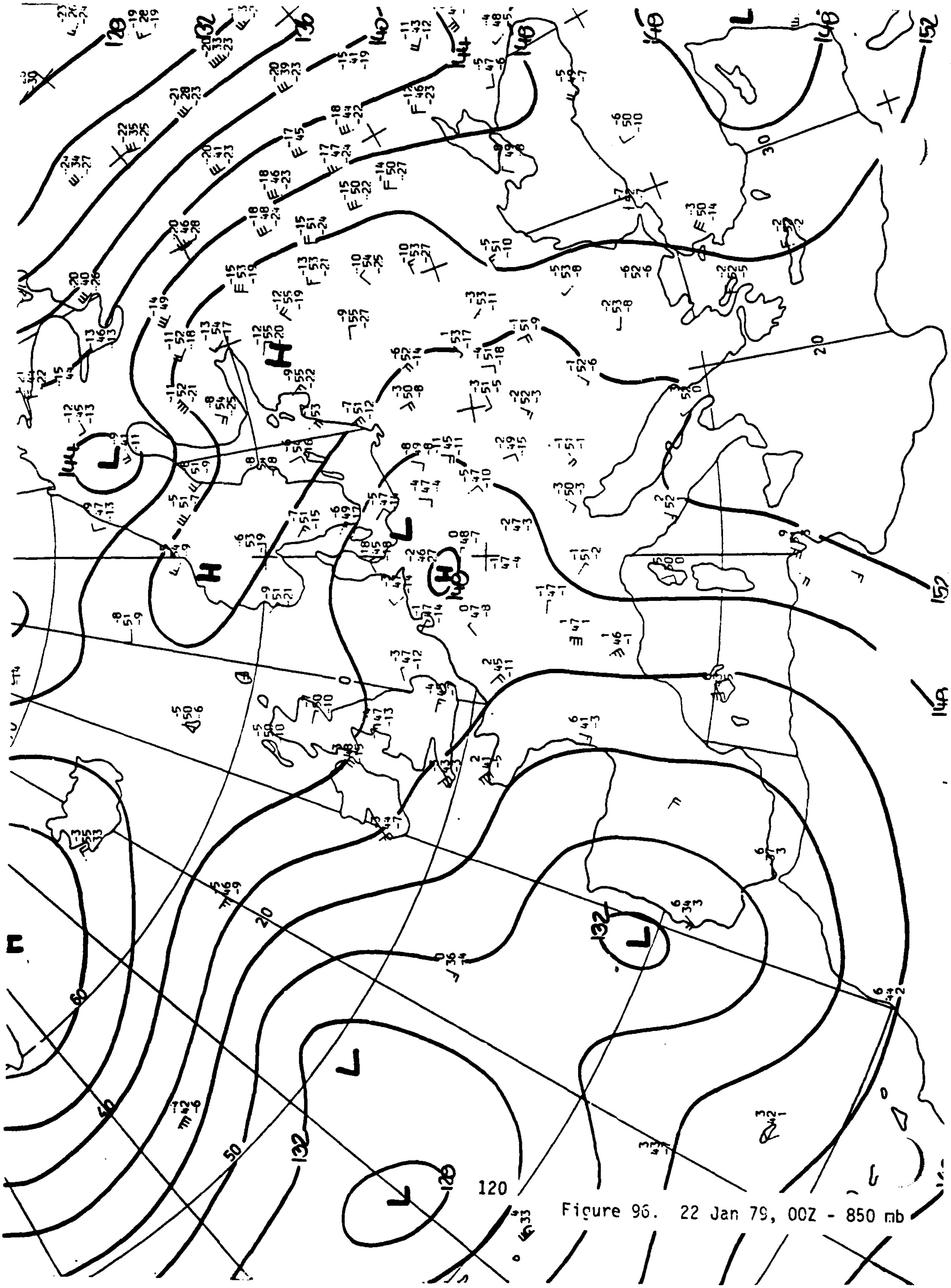

Figure 96. 22 Jan 79, 00Z - 850 mb

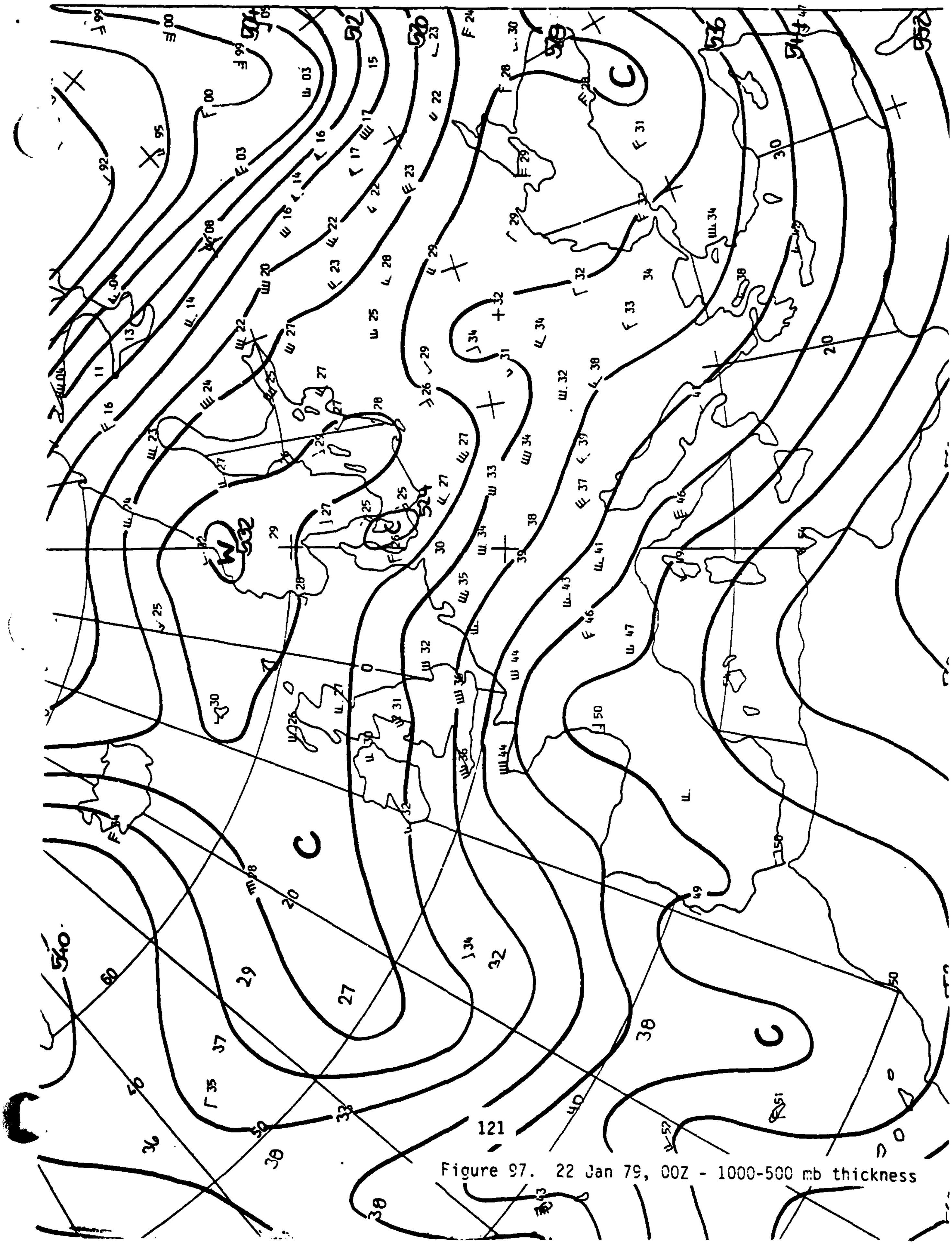

Figure 97. 22 Jan 79, 00Z - 1000-500 mb thickness

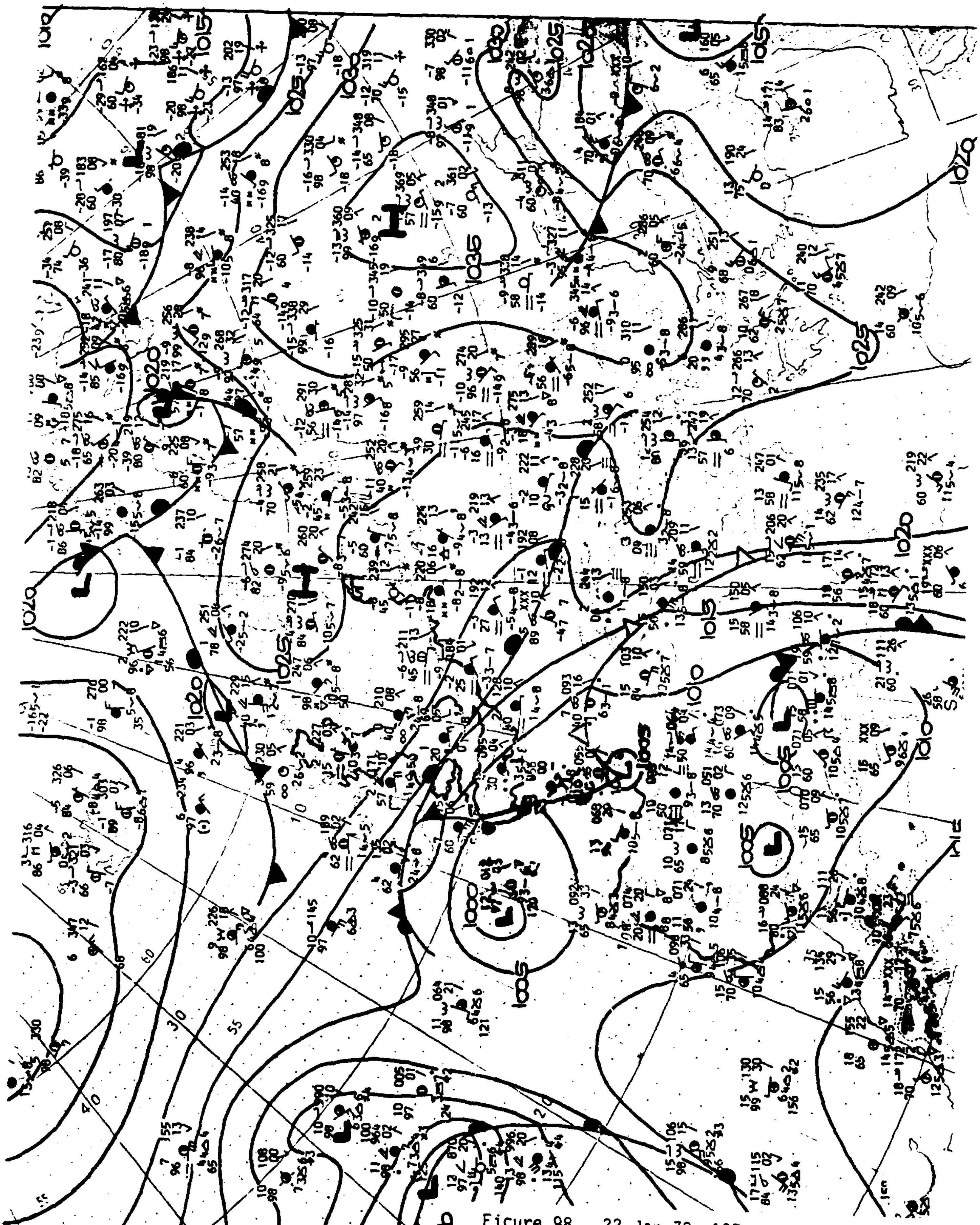

Figure 98. 22 Jan 79, 12Z - surface analysis

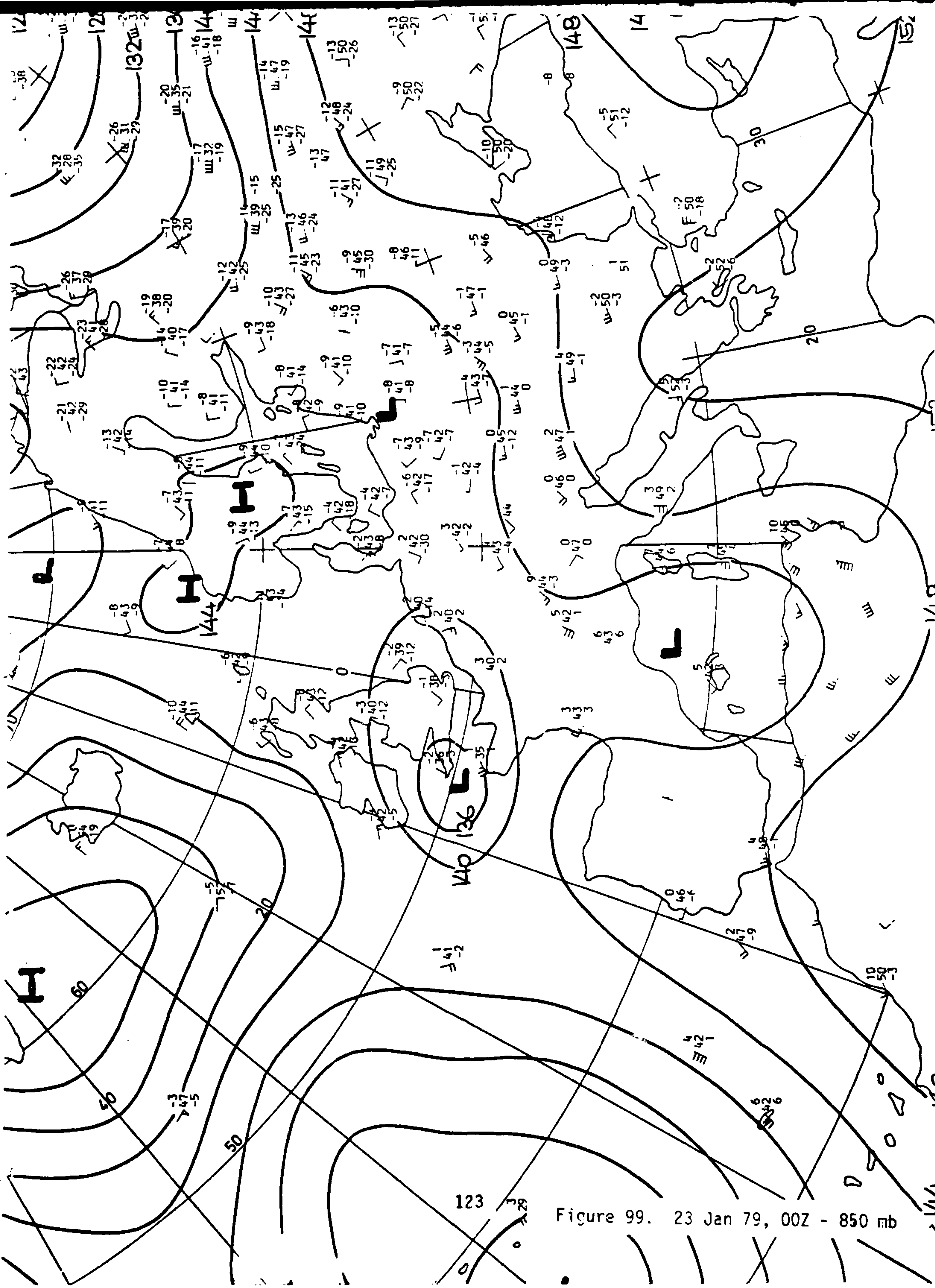

Figure 99. 23 Jan 79, 00Z - 850 mb

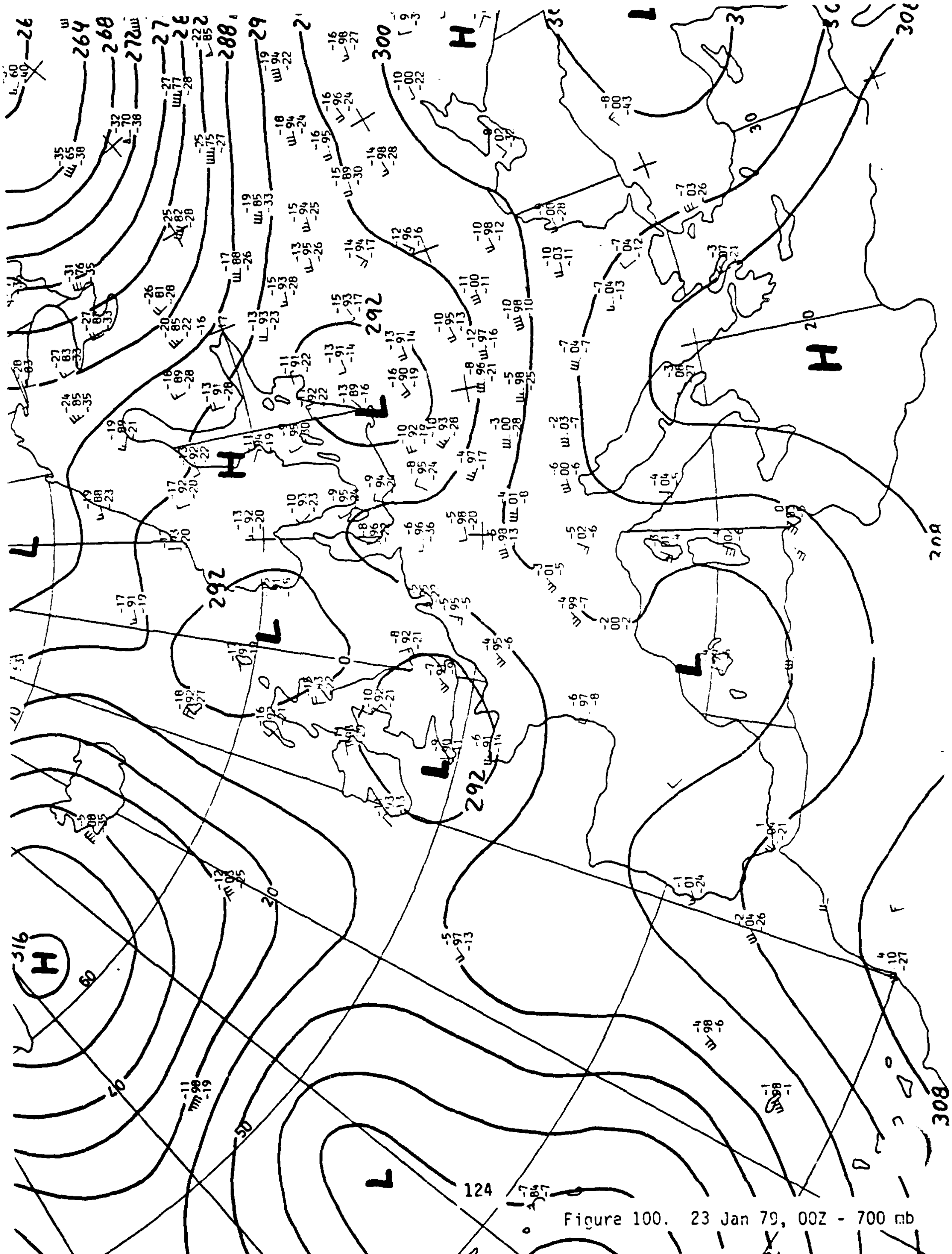

Figure 100. 23 Jan 79, 00Z - 700 mb

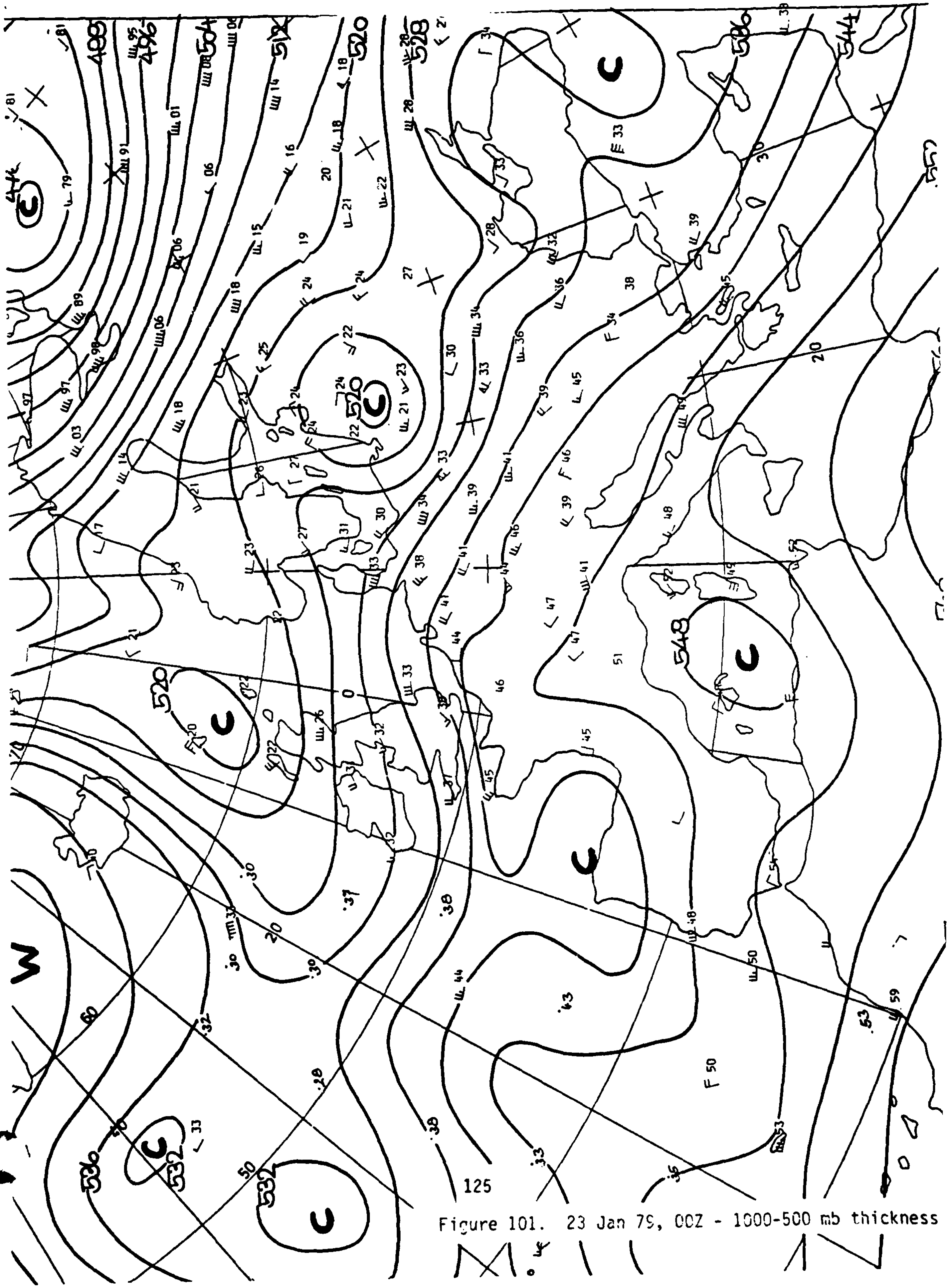

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Figure 101. 23 Jan 79, 00Z - 1000-500 mb thickness

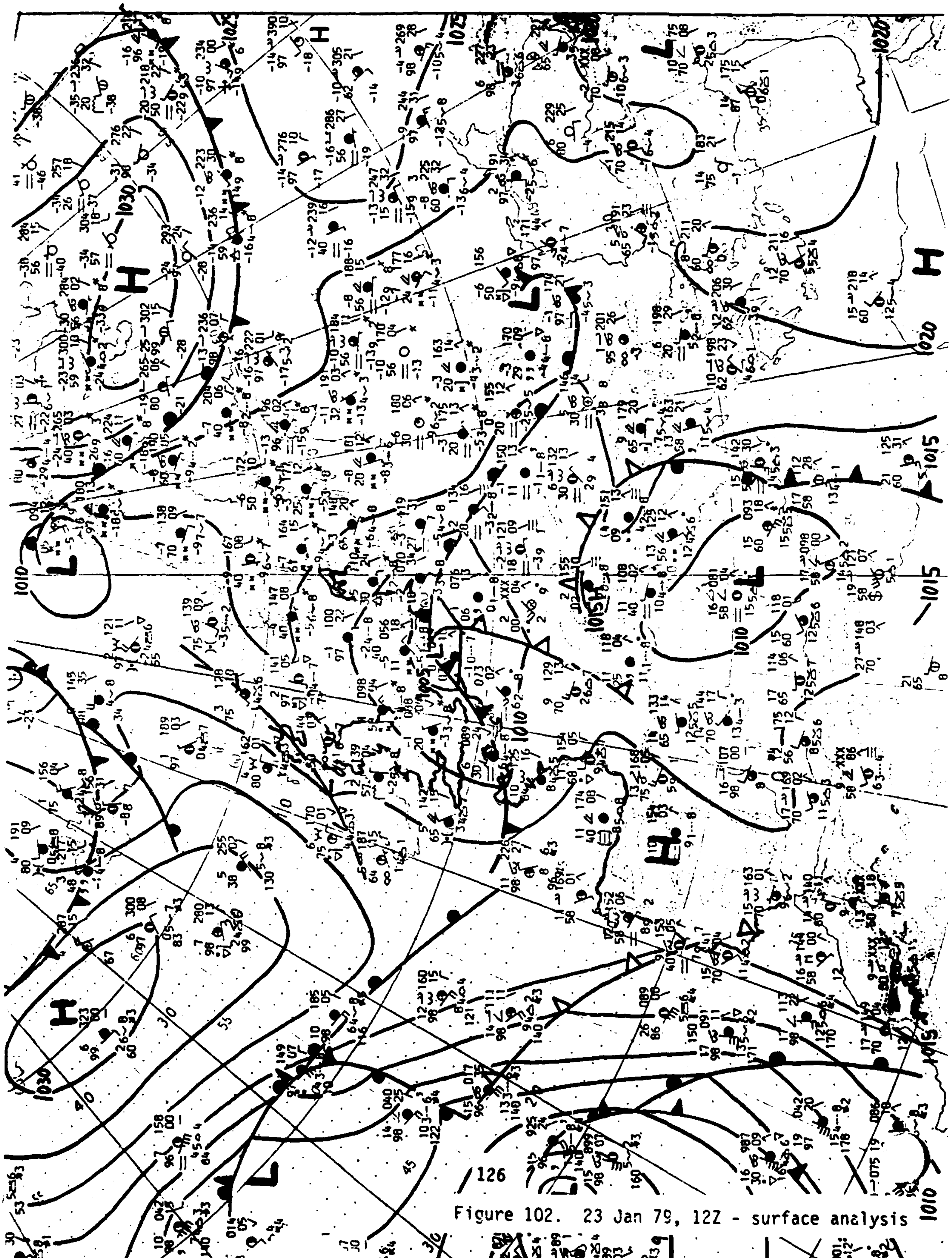

Figure 102. 23 Jan 79, 12Z - surface analysis

CHAPTER 3

Conclusions

1. The cases from Chapter 2 clearly show that forecasting freezing precipitation is anything but easy. It requires forecasting precipitation areas, surface and upper air temperatures, and also winds, because turbulence and terrain are important factors. Table 2 in Chapter 1 provides some guideline based on history which can be checked against the cases in Chapter 2. But again, these guidelines only work if surface temperatures and precipitation areas are correctly forecasted. The following observations are made with respect to Chapter 2:

a. Freezing precipitation is not restricted to warm fronts. It can occur with cold fronts or warm frontal occlusions.

b. Freezing precipitation is independent of wind direction though there are local variations due to terrain.

c. Frontal orientation is not a good predictor.

d. Freezing precipitation is not confined to Atlantic air intrusions into the cold continent - it can occur with cold fronts which move westward from eastern Europe.

e. Freezing precipitation does not always turn into rain; it can turn into snow if the jet stream remains or moves south of your station.

f. Freezing precipitation is not an early morning phenomenon. Advection rather than insolation is the key factor.

g. If freezing precipitation occurs with a trough passage, it will be followed by either rain or snow, depending on surface temperatures.

2. As a result of the information given in Chapters 1 and 2, a workshop held at 31 WS/DN on 25 October 85 developed a freezing precipitation worksheet (Appendix 2).

3. The question of false alarms was raised at the workshop. Admittedly, the worksheet is not a fool-proof method for forecasting freezing precipitation. It is only a guideline, but we think it's a good one. False alarms can be attributed to incorrectly forecasting the rain band or the surface temperature. False alarms are also possible by working with thickness. An accurate thickness forecast is essential. If it's not possible, use other techniques. There are, however, marginal cases where numerical progs plus the correct application of the worksheet can lead to a false alarm. The most prominent case follows.

4. A False Alarm. 13-14 December 1981. On 13 Dec 81, at 12Z (fig 103), the surface analysis looks very familiar: a low just off Ireland, a warm front stretching along the French Atlantic coast into the Mediterranean, and a high over southern Germany. Temperatures are below freezing over Germany, the Benelux, and northern and central France. Unlike the cases in Chapter 2,

heavy snowfall is observed over Normandy, where southeasterly winds are advecting cold air from central France into the English Channel. The front is moving due east into Germany. Upper level analyses from 14 Dec, 00Z (fig 104 and 105) show cold temperatures ahead of the front at both 850 mb and 700 mb. Soundings over France are missing (a good example of data outage). From the Crawley sounding though, it can be summarized that 850 mb temperatures are -1°C behind the cold front which is a good "no snow forecast hint". Consequently, the forecast should call for snow ahead of the front, turning into freezing precipitation, after frontal passage. This is also supported by the 1000-500 mb thickness (fig 106) which shows thicknesses greater than 5350 gpm. But freezing precipitation is only observed at Ramstein AB which is located in a sheltered valley. What failed? The surface temperatures rose above 0°C after frontal passage so the precipitation turned from snow into rain leaving out the freezing precipitation stage. Are strong winds the reason? Cases in Chapter 2 show that strong winds alone cannot remove the cold layer quick enough to prevent freezing precipitation. On the other hand, the surface inversion weakens when the 850 mb winds are light. The main reason is the strength of cyclonic curvature. The stronger the cyclonic curvature, the quicker the cold air is displaced in the low levels. This tool worked on 14 Dec 81.

5. Based on our experience with freezing precipitation, we offer a few additional hints:

a. If upstream temperatures are below freezing, if anything, forecast below freezing temperature at your station.

b. Increasing cyclonic curvature will weaken or remove a low level inversion.

c. Upslope flow keeps it cold at your station, downslope flow causes warming. THINK TERRAIN!

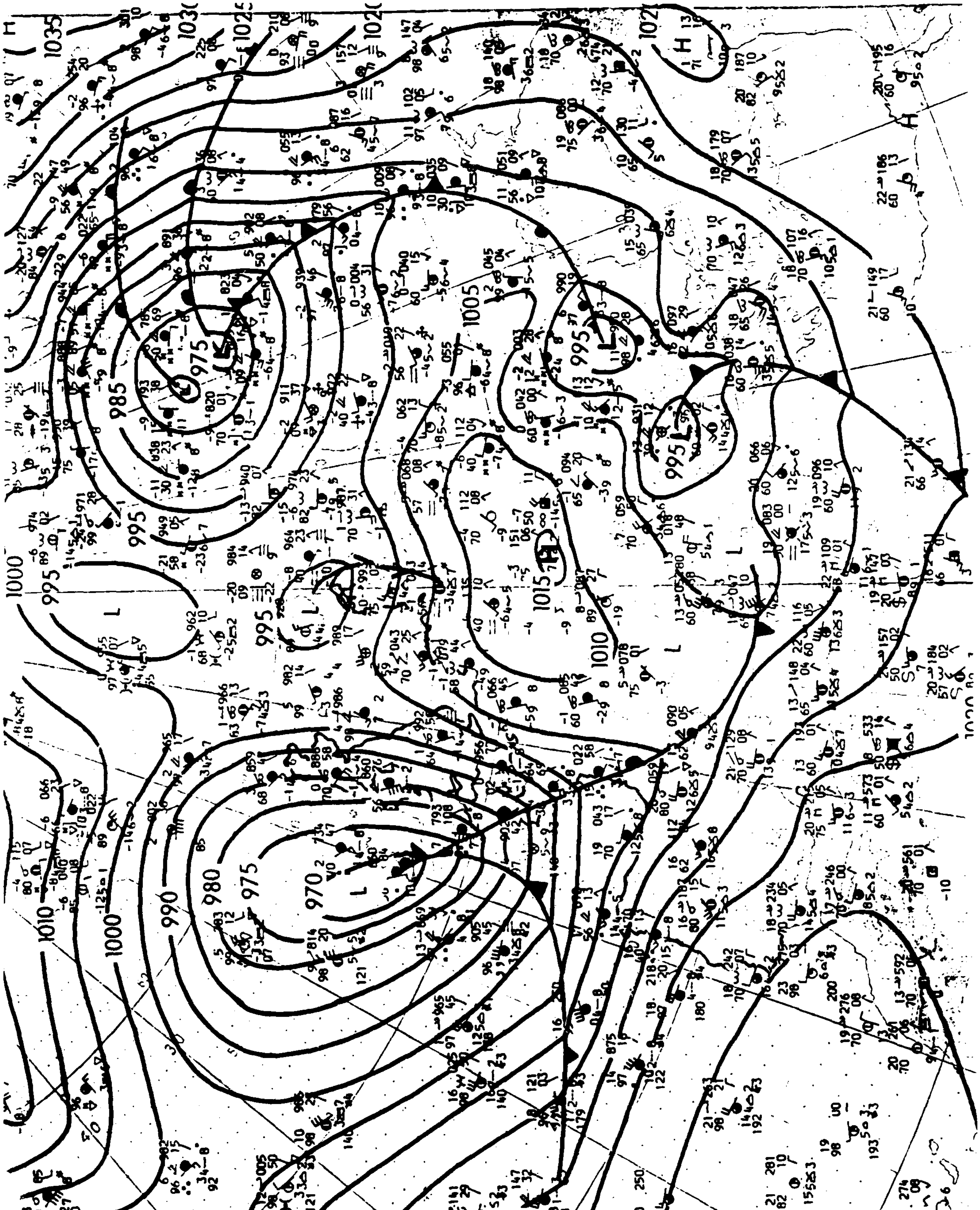

Figure 103. 13 Dec 81, 12Z - surface analysis

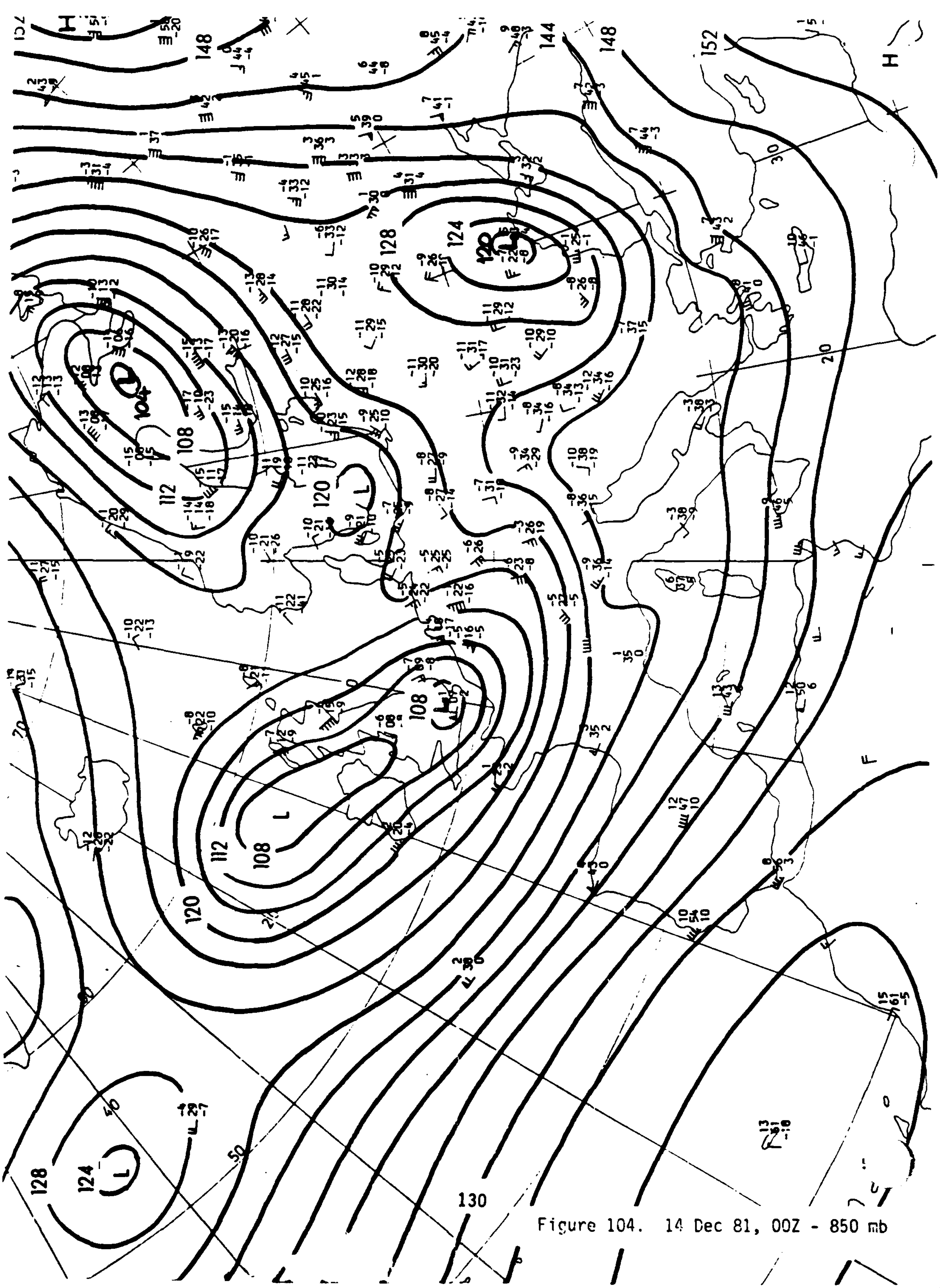

Figure 104. 14 Dec 81, 00Z - 850 mb

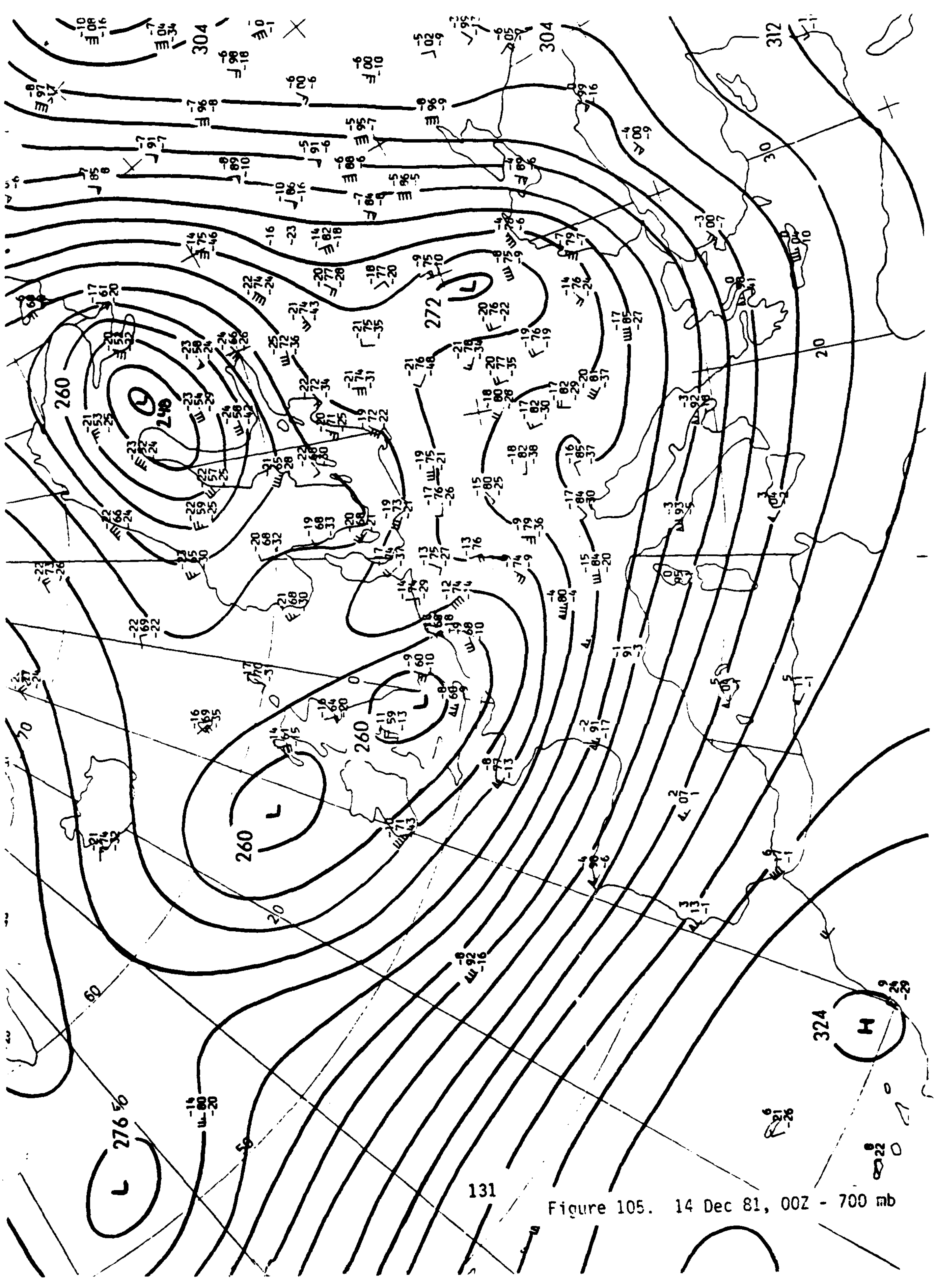

Figure 105. 14 Dec 81, 00Z - 700 mb

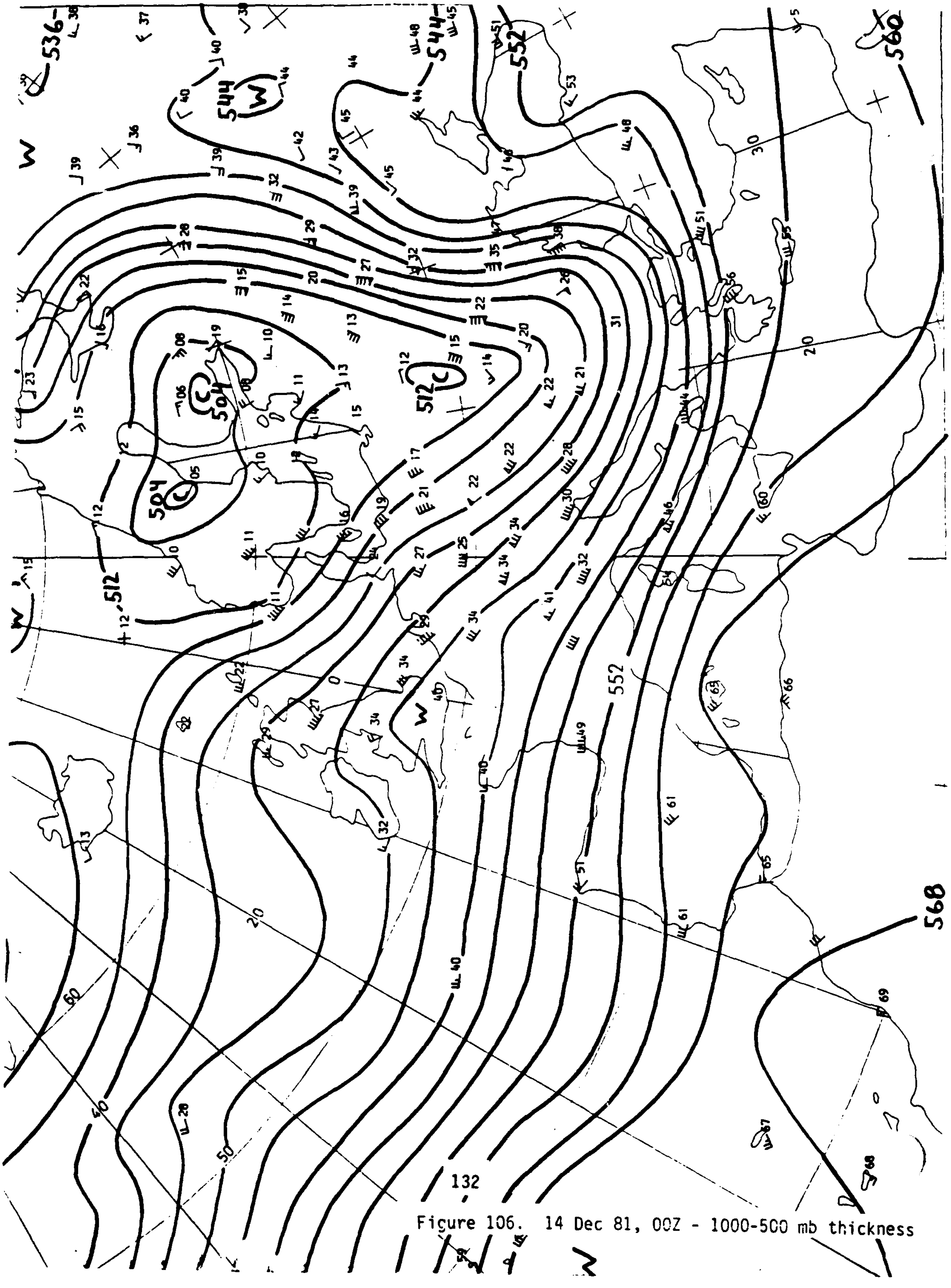

Figure 106. 14 Dec 81, 00Z - 1000-500 mb thickness

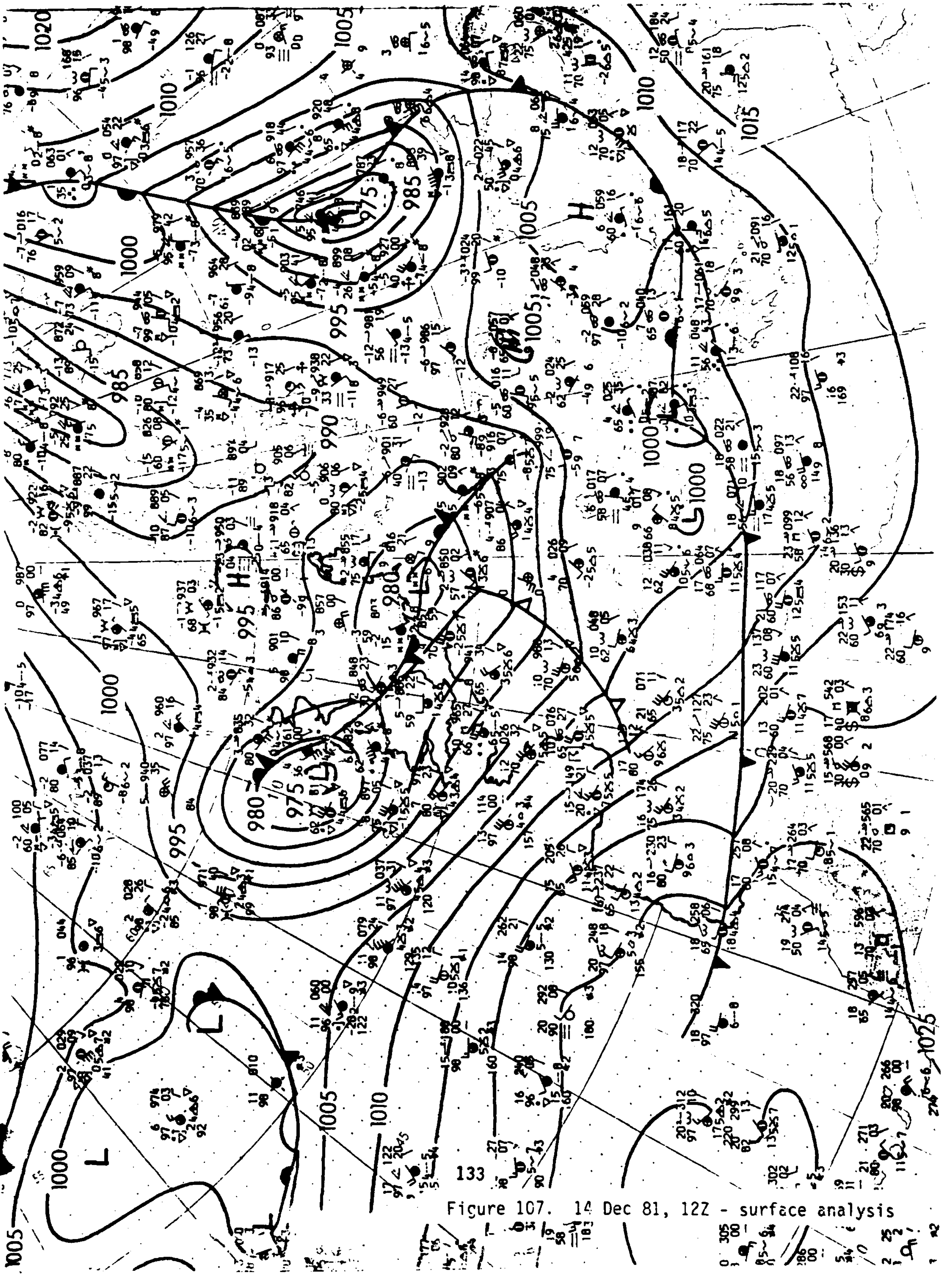

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Figure 107. 14 Dec 81, 12Z - surface analysis

APPENDIX A

FREEZING RAIN - THE DUTCH METHOD*

The Dutch method for forecasting freezing precipitation is presented for your appraisal. Unlike most other methods, it is based on the lowest 850 mb of the atmosphere. According to the KNMI (Royal Netherlands Meteorological Institute), the method has a reasonable rate of success. According to the Dutch operational forecasters at Soesterberg Air Base the method does work very well. The following checklist should be used in preparing a chart for parameter analysis:

1. Look for a typical FZ precipitation generation pattern. Warm air over cold pool with the approach of a warm front, for instance.

2. Choose some representative soundings.

3. Plot each parameter in the following model:

   T^{max} 850-1000mb   Thickness 850-1000mb

   $T_{surface}$

4. Do an analysis (isopleths) for each parameter. (see Figure A.1)

5. Forecast the 850mb position of the -4°C isotherm and draw that boundary. (Atch 1)

6. Where all areas drawn by isopleths intersect, and the temp at 850mb is greater than -4°C, is the forecast boundary of freezing precipitation.

*Presented by Lt Steve Ricci; OL-A, 31 WS

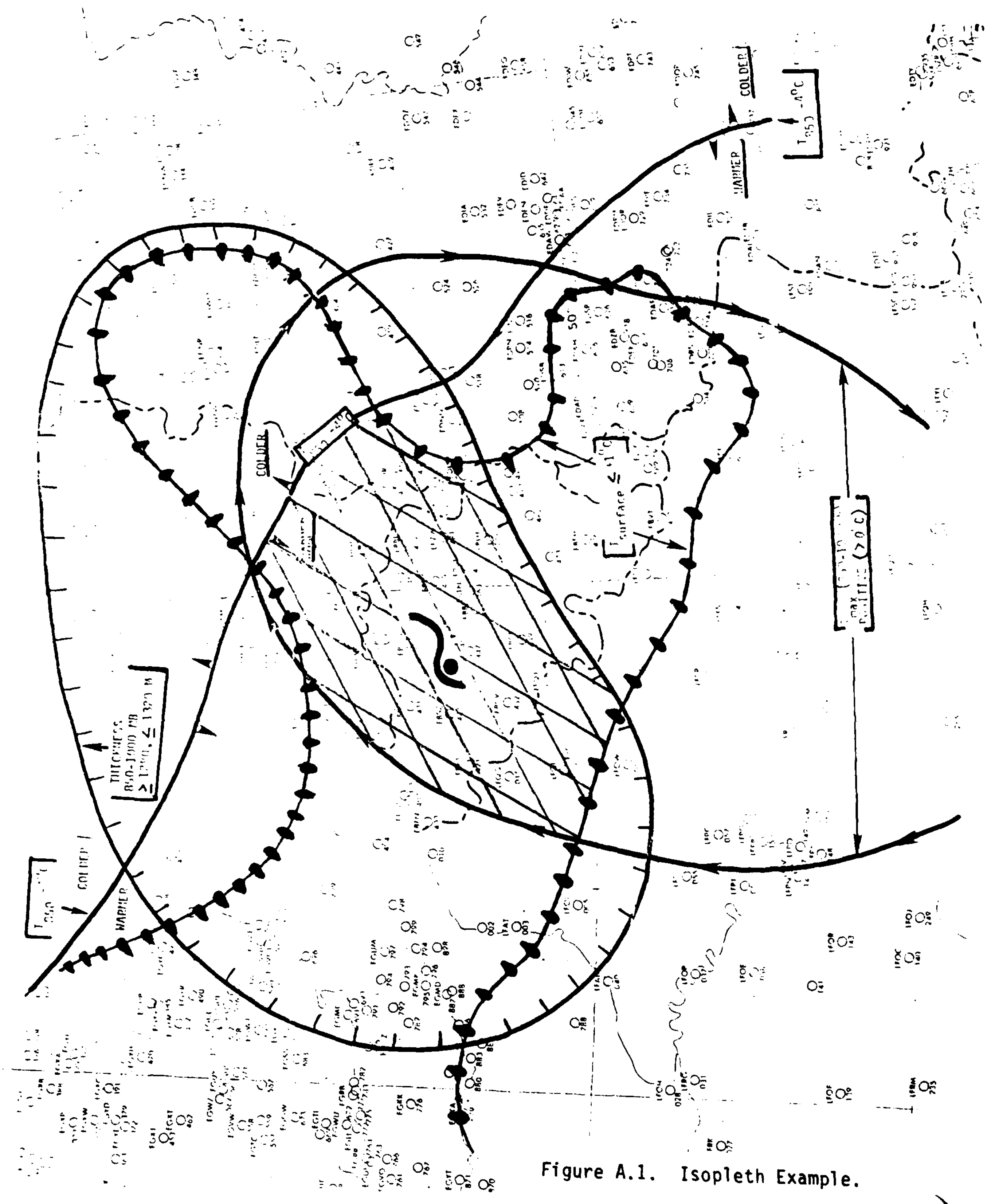

Figure A.1. Isopleth Example.

APPENDIX B

Freezing Precipitation Worksheet

TYPICAL SYNOPTIC PATTERNS

- Cold dome over Central Europe, result of high press over USSR pumping in cold air.

  -- Watch for frontal systems or waves moving onto continent through France or Benelux.

- Gulf of Genoa low moves south of Aviano pushing warm air north.

PARAMETERS FAVORABLE FOR FZ PRECIP

	YES	NO
- SFC temp < 0 for at least 12 hrs (adjust for higher terrain)	____	____
- 850 temp > -4^{0}	____	____
- Warmest temp aloft is $\geq$ 0	____	____
- 1000-850 thickness 1280-1320m	____	____
- 1000-500 thickness 5350-5450m	____	____

HINTS

- For units in Germany, if it's raining in France and your SFC temp $\leq 0^{0}$, think FZ precip.

- Can get FZ drizzle when warmest temp in sounding is -2.

- If coastal French STNS report SFC temp $\geq$ +10 and SFC temps in Germany $\leq$ 0, forecast FZ precip or precip but not snow.